GROWTH SUBSTANCES & THEIR PRACTICAL IMPORTANCE IN HORTICULTURE

H. L. PEARSE

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GROWTH SUBSTANCES AND THEIR PRACTICAL IMPORTANCE IN HORTICULTURE

By

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FOREWORD

By Dr. C. H. Neveling, Secretary for Agriculture, Union of South Africa.

The history of research on growth promoting substances is a fascinating one and the results already achieved are of outstanding importance both to science and practice.

Indeed, it can safely be said that since the discovery of the hormone system in plants and the subsequent synthetic production of growth promoting substances, few subjects have had a greater stimulating effect on research, and from fewer still has flowed forth so much that could find immediate practical application.

It is therefore not surprising that horticulturists the world over are inclined to view these developments not only as the dawn of a new era, in which exact knowledge will replace trial and error methods, but in several respects also as a panacea that will solve many of the troubles of the industry.

The decision to publish a new technical communication on this subject, which will summarize the scattered literature and at the same time sketch the extent of our knowledge and the limitations of its application in practice, is most timely and will serve a useful purpose for the research worker and eliminate much misunderstanding and misguided enthusiasm among practical horticulturists.

As in his previous publication Dr. Pearse has been eminently successful in producing a manuscript of undoubted value to the scientific worker and yet understandable to the intelligent practical man, at best a difficult task.

The fact that Dr. Pearse has been chosen for this task gives me great pleasure, firstly because the Bureaux are now giving effect to the desire among Commonwealth scientists for greater collaboration in their work and secondly, of course, because he happens to be a South African now. Apart from the fact that Dr. Pearse has for years been actively associated with research in this field, the Bureaux, in putting the above policy into effect, could have made no more fitting choice, than of someone who, in adopting a new home, has acquired the language of the country and applied himself to its problems, thus demonstrating the spirit of true collaboration which we all desire.

INTRODUCTION

From the early beginnings of human development man has cultivated plants in order to supply his needs, and over the centuries has slowly built up a mass of technical detail, the art of horticulture. Even to-day most of the methods in current use in horticultural practice are based on experience gained by empirical methods of trial and error. Modern plant physiological and biochemical science is yet far from fully elucidating the basic reasons for the success or failure of various horticultural operations, but nevertheless here and there a glimmer of fundamental truth is laid bare and opens up the way for rapid advancement in practical technique.

The discovery of the hormone system in plants, culminating in the isolation and later the synthetic production of numerous substances which regulate the growth of plants, has been one of the outstanding achievements of modern plant science. To-day, these substances have found many and varied uses in the commercial culture of plants, and are helping the grower to exercise more and more control over his plant material. New ways in which they can be used to advantage by the practical horticulturist still continue to come to light, and in fact so great has been the interest in the practical uses of these substances that in some directions utilitarian exploitation has got ahead of fundamental knowledge and much more basic research must be carried out before their mode of action is fully understood. The plant responses observed in tackling practical problems nevertheless suggest new methods and new angles of investigation for the fundamental scientist and thus are a powerful stimulant to further progress.

Among recent, though now firmly established, practices which have resulted from research on synthetic growth substances is their use in the propagation of plants ; their use in improving set and producing seedless fruit in tomatoes ; their use for preventing pre-harvest drop of apples and pears and their very recent use as powerful and selective herbicides. In addition very many other ways in which they are likely to be of practical value have been partially investigated, although the stage for practical recommendations has not yet been reached.

Contributions to the subject have been extremely numerous during the past two decades and new publications continue to pour out in a steady stream. The relevant information is widely scattered throughout numerous technical and popular journals and in this brief review an attempt has been made to bring together this dispersed information. The literature is so bulky that it is quite possible that some important contributions have been overlooked, but it is hoped that the main trends of advance have been adequately covered. While no attempt has been made to discuss the more fundamental aspects of the subject in the text, except in so far as has been necessary in explaining practical results, a considerable number of the more important references to the basic research are included in the bibliography.

THE USE OF GROWTH SUBSTANCES IN VEGETATIVE PROPAGATION

I. THE GROWTH OF THE CONCEPT OF ROOT-FORMING SUBSTANCES.

A. Evidence for the existence of a root-forming substance.

The existence of a specific root-forming substance in plants was postulated by Sachs (1880) and this substance was visualized as being formed in the leaves and from there moving downwards towards the base of the stems. If a stem was cut it was presumed that this substance would accumulate at the basal cut end, and there exert its effect in promoting root formation. The fact that the leaves are also the seat of carbohydrate formation and of other nutritional substances which are also transported from there to other parts of the plant, led to a certain amount of confusion, however, and thus, while many observers including Beijerinck (1886) noted that the presence of leaves stimulates root formation in cuttings, they regarded this as mainly due to the nutritional factors. Van der Lek (1925) showed that root formation in cuttings of *Salix, Populus, Ribes* and *Vitis* species is largely dependent upon the existence of buds, especially strongly sprouting ones. Roots can be produced in cuttings from which all the buds have been removed, but they are less abundant and smaller than in cuttings with buds present. Van der Lek therefore assumed that one or more hormone-like substances are formed in sprouting buds, and are then transported in a basal direction through the phloem and stimulate root formation. In certain cases where abundant root formation did occur in cuttings with excised buds, he was able to demonstrate, by microscopical examination, the existence of root germs or initials already formed, which are therefore likely to develop without the necessity for the presence of the hormone. The elucidation of the action of leaves and buds was carried a stage further by Went (1929). Using cuttings of *Acalypha*, he was able to show that root formation depended largely on the presence of leaves and buds, the buds having rather more influence than the leaves. Cuttings which had been defoliated and debudded produced very few roots or in some cases none at all. It was found, however, that if an extract obtained from Papaya leaves was mixed with agar, and applied to the defoliated and debudded cuttings there was an increase in the number of roots formed by such cuttings. Bouillenne and Went (1933) found that extracts of rice polishings were also active in promoting the formation of roots. The action of the extracts was only exerted at the base of the cuttings, and inversion of the cuttings with respect to gravity did not influence this polarity ; it was therefore concluded that the active root-forming substance could only move in one direction in the cutting, from apex to base, and accumulating at the base promoted root-formation there. They named this special root-forming substance " rhizocaline" and an examination of its properties showed it to be thermostable and definitely not a nutrient substance, but to be produced by the leaves in the presence of light, and transported only in the basal direction.

In the search for other sources of this active substance Laibach (1934), Laibach, Müller and Schäfer (1934) and Müller (1935) showed that extracts of urine and pollen applied to the internodes of *Coleus* and *Tradescantia* plants were active in promoting the formation of adventitious roots. That certain bacteria might also be a source of root-forming substances was indicated by the work of Němec (1930) who noted that smearing the cut surface of *Cichorium intybus* with cultures of *Bacterium tumefaciens* had a stimulating effect on the production of new roots. Němec (1934) also obtained increased root formation on isolated hypocotyls of *Helianthus* and *Lupinus* by soaking them in extracts of cotyledons, terminal buds or stems. It was clear therefore that the active root-forming substance was of widespread occurrence in plant material.

B. Quantitative estimation of root-forming activity.

The discovery that root formation is controlled by special root-forming substances naturally made felt the need for some method of quantitative estimation. A convenient and reasonably accurate biological method was worked out by Went (1934b) using etiolated pea shoots. The procedure used was a follows: Seeds of a pure strain of *Pisum sativum* were disinfected with mercuric chloride solution and then just covered with water and allowed to soak for from 4 to 6 hours. They were then planted in well-washed sand in seed pans, and the pans were placed in a dark room maintained at a high humidity (85 to 90 per cent.); all further manipulation was carried out in faint red light and at a constant temperature of 25° C.

A week after planting, when the plants were about 10 to 15 cm. high, they were cut off at about 1 or 2 mm. above the first node. At the first and second nodes only scales developed, but on the third node a normal leaf appeared. The tip of the shoot was next cut off just under the third node, leaving a stem piece consisting of the second and third internodes.

A number of these cut shoots were then placed together, for about 4 hours, with their bases in water, and for the following 4 hours this was replaced by a 0·05 per cent. solution of potassium permanganate, for disinfection of the material. One ml. of the solution to be tested for root-forming activity was then placed in each of a number of bottles of diameter about 1 cm. The bottles used were thoroughly cleaned and special care was taken to remove all traces of oxidising agents. The test shoots were then removed from the permanganate at the end of 4 hours and their bases were rinsed in distilled water; the apical parts of the cuttings were then slit lengthwise down the middle for a distance of about 1 cm., by means of a razor blade. The apical slit ends were then immersed in the test solutions for about 12 to 15 hours, the operations being performed in a dark room at 25° C., with a medium humidity of 60 to 70 per cent. Five cuttings were used for each bottle. At the end of this time the immersed ends were rinsed with water and the cuttings were placed basal ends down in 5 ml. of 2 per cent. sucrose. The sucrose used was extracted previously with ether or chloroform to free it from substances which might affect the validity of the test.

After six days in the sugar solution the cuttings were transferred to tap water, and roots allowed to develop. For root development after treatment, the most favourable conditions were found to be in a dark room at 25° C. and at 60 to 70 per cent. relative humidity. The first roots developed 4 to 5 days after treatment, the sooner, the higher the concentration of the root-forming substance. The final root count was made 14 days after treatment with the test solution, as it was found that the number of roots does not increase after this interval. Went found that there was an approximate linear relationship between the concentration of the root-forming substance used, and the number of roots produced. A few roots were produced on water-treated control cuttings which he presumed was due to root-forming substances stored in the scales of the test shoots. Roughly quantitative estimations could also be made by mixing the test extract with lanolin and applying this as a paste on the radial cut surfaces of the apically split shoots.

C. Isolation and nature of the root-forming substances.

Using the pea root test outlined above Thimann and Went (1934) were able to investigate the properties and nature of the root-forming substance, and in the course of this work they were impressed by its similarity to other natural plant hormones which had been discovered by investigations into the nature of tropisms and correlation in plants.

Anyone who has tried to grow plants in a window is familiar with the fact that plants grow and curve towards the light. In (1880) Darwin made a careful study of this bending response of plants to light, using as his experimental material the first leaf (a cylindrical organ known as the coleoptile) of a grass, *Phalaris canariensis.* He found that the coleoptile only perceives the light stimulus in the region just below the tip. If this tip was removed, or covered with dark paper no bending occurred in response to the light stimulus, although the region in which curvature normally occurred was some distance below the tip. Following Darwin, various workers including Boysen Jensen (1910-11), Paal (1918), Stark (1921), Söding (1925), Seubert (1925) and Went (1928) investigated the mechanism by which this curvature took place and the nature of growth in the coleoptile, using mainly the oat plant *Avena sativa.* A full historical account of this work can be found in books by Boysen Jensen (1936*b*) and Went and Thimann (1937a).

The important point was that it was finally demonstrated that there is a substance produced in the tip of the coleoptile which is transported downwards and brings about enlargement of cells in the lower zone. Thus in observations on the straight growth of the coleoptile it was noted that if the extreme tip of the coleoptile be removed (1-2 mm.), growth stops. If, however, the tip is replaced on the decapitated stump growth is resumed. The active substance responsible for the cell enlargement in the coleoptile could be extracted from the coleoptile tips by placing them on thin sheets of 3 per cent. agar. If the agar on which such tips have been standing is cut into small blocks and these blocks are then placed on the stumps of decapitated coleoptiles, growth starts again in the stump.

The actual amount of growth is small, but Went (1928) elaborated a technique whereby the small agar blocks are placed in contact with one side only of the coleoptile stump. The active substance is then transported down this side causing a growth response on this side only with the result that the coleoptile bends and over certain limits the angle of bending is proportional to the amount of active substance present in the agar block. It was therefore clear that the growth of the coleoptile is regulated by a definite chemical substance. This substance was named auxin, and from analogy with the term hormone, which had been used by the animal physiologists to denote a substance produced in one tissue which is able to influence in some specific way the functional activity of another tissue, it is evidently a plant hormone.

This bending response of the cut coleoptile to unilaterally applied auxin when carried out under fully controlled conditions, usually in a dark room at 22° C. and 92 per cent. relative humidity, provided a quantitative means of estimating amounts of auxin present in plant material and other sources, and in fact still remains, with refinements, the standard method of estimating naturally occurring hormones.

Using this method it was found that auxin is apparently widespread throughout the plant kingdom, in roots, in stems, in germinating grain and even in plant derived materials. Kögl, Haagen-Smit and Erxleben (1930) succeeded in extracting from urine three substances which were extremely active as measured by the coleoptile test and one of these active substances proved to be β-indolylacetic acid, a compound which had been known to chemists long before. This active compound was also found in moulds such as *Aspergillus niger and Rhizopus.* More recently Haagen-Smit, Leech and Bergren (1941) have isolated indolylacetic acid from the auxin liberated by the alkaline hydrolysis of corn meal and dormant maize kernels, and this has been confirmed by Berger and Avery (1944), while Haagen-Smit, Dandliker, Wittwer and Murneek (1946) found that the free auxin extractable with 95 per cent. alcohol from immature maize kernels consisted chiefly of indolylacetic acid in amounts of $2 \cdot 68 \times 10^{-5}$ g. per 1 g. of kernel. Auxin activity is therefore now usually estimated in terms of units of indolylacetic acid.

Thimann and Went (1934) using the pea root test, found that the root-forming substance was present in a number of pollens and other natural products and occurred almost always together with auxin (detected by its effect on the oat coleoptile). In many cases, in fact, there was even a good quantitative parallelism between root-forming and growth-promoting activity ; thus an extract of *Rhizopus*, rich in auxin, was also very rich in the root-forming hormone. They found that the root-forming substance was extractable by organic solvents, from acid solutions only, and is therefore an acid. The distribution between different solvents was the same as that of auxin. Its activity was readily destroyed by oxidizing agents and followed that of auxin throughout the various stages of purification, even through vacuum distillations. Therefore, although it was not proved that the substance was identical with auxin, the evidence pointed strongly in that direction.

With the recognition that β-indolylacetic acid is an active growth promoting substance, it was not long before this substance was tested for root-forming activity. Thimann and Koepfli (1935) and Kögl (1935) found, in fact, that synthetic β-indolylacetic acid was as active in root formation as the purest *Rhizopus* preparation. This was considered proof therefore, that one at any rate, of the hormones causing root formation is identical with auxin.

The special term "rhizocaline" for the root-forming hormone was therefore no longer necessary, although root-forming and growth-promoting activities of various natural preparations did not always appear to be quantitatively parallel, as estimated by the biological methods.

D. Early work leading to practical application in propagation.

The discovery of indolylacetic acid as an active root-forming substance, led naturally to an examination of its potency in causing root formation in intact plants and later in cuttings. This substance also had the advantage of being readily prepared synthetically and also being relatively stable. Laibach (1935), Fischnich (1935) and Laibach and Fischnich (1935) observed that adventitious roots could be produced on intact plants of *Coleus*, *Vicia faba* and the tomato (*Solanum lycopersicum*) by dissolving β-indolylacetic acid in sheep's wool fat (lanolin) and applying this preparation as a paste to the stem. Cooper (1935) was the first worker to investigate the practical use of β-indolylacetic acid for rooting cuttings and he found that applying a paste of this substance in lanolin to the apical part of lemon cuttings greatly stimulated root formation at the base of the cuttings. The reason for the apical treatment in this early work was that it seemed more nearly to copy the normal production of the natural hormone in the leaves and buds and its transport to the base. Shortly afterwards, however, Cooper (1936) and Hitchcock and Zimmerman (1936) found that, with appropriate concentrations, basal treatment of cuttings was very effective and much more convenient in practice.

At the Boyce Thompson Institute in New York investigations had been proceeding for some years on the effect of illuminating gas on the growth of plants, and it had been observed that one of the effects of exposing tomato plants to either ethylene vapour or carbon monoxide gas was to cause the initiation of adventitious roots on the stems of the plants. The similarity of this effect and the production of roots by application of β-indolylacetic acid was realized and therefore, in view of the fact that root-forming properties were evidently not specific to naturally-occurring hormones, Hitchcock (1935) and Zimmerman and Wilcoxon (1935) were encouraged to test many other substances for their root-forming capacity, some closely related to indolylacetic acid and some differing widely in chemical constitution. In this way they discovered several more substances active in promoting root-formation, some of the most active of which were phenylacetic acid, phenylpropionic acid, indolylpropionic acid, and α-naphthaleneacetic acid. Their preliminary tests were carried out using the tomato as the main test plant, but they immediately proceeded to test the effectiveness of these substances for rooting cuttings of many different species of plants, with quite remarkable results in some cases, the number of roots per cutting being greatly increased, and the time taken for roots to appear greatly reduced.

Hitchcock and Zimmerman (1936) carried out large scale tests on the rooting response of cuttings, after allowing the cuttings to absorb the active substances from dilute solutions in which the basal ends of the cuttings were stood. The following crystalline acids were used, indolylacetic acid, indolylbutyric acid, indolylpropionic acid, phenylacetic acid and α-naphthaleneacetic acid.

Solutions of each hormone were prepared by first dissolving the crystals of the pure substance in a few drops of 95 per cent. ethyl alcohol and then adding the required amount of tap water. The low solubility of these substances in water made such a procedure necessary in order to obtain rapid solution. Dilutions were made from a standard stock solution containing as a rule, 20 mg. per 100 ml. water. Fresh stock solutions were made each day and control tests showed that the small amount of alcohol present was without effect on the plant material.

The treatment was as follows :—the basal ends of the cuttings were placed in minimum amounts of the test solution, to a depth of about ½ to ¾ inch. After remaining in the solution for the required period, usually from 6 to 48 hours, the cuttings were planted in the rooting medium in a greenhouse, together with control batches which had remained in tap water for the same period.

The rooting mixture consisted of sand and peat moss 1/1, and some or all of the leaves were left on the lower part of the cuttings. The cuttings were then placed in the rooting mixture so that from ⅔ to ⅞ of the stem was buried and the leaves lay close to or nearly flat on the surface of the substrate. Cheesecloth was placed over the cuttings for the first 10 days to 3 weeks and was only removed during periods of continuously cloudy weather.

Much improved rooting was obtained with cuttings of several species as the result of treatment. Some effective treatments were :—*Ilex opaca* Ait. : indolylacetic acid 20 mg. per 100 c.c. with immersion for 6 to 48 hours, *Ilex crenata* Thunb. : indolylbutyric acid 0·4-2 mg. per 100 c.c. for 16-24 hours or α-naphthalene acetic acid, 2-5 mg. for 16-24 hours, *Pachysandra terminalis*, Sieb. and Zucc. : α-naphthaleneacetic acid, 2-10 mg. per 100 c.c. for 24 hours, and *Hibiscus syriacus* L. : indolylbutyric acid, 0·8-4 mg. per 100 c.c. for 3 days.

In some cases the compounds were applied as lanolin pastes. The synthetic crystalline compounds were mixed with lanolin in amounts ranging from 0·1 to 100 mg. of the substance to 1 g. of lanolin (0·01 to 10 per cent.). The vessel containing the mixture was immersed in warm water long enough to melt about half the lanolin and the preparation was stirred thoroughly with a glass rod. These pastes were applied to shoots of intact plants, and cuttings were then gathered subsequently, by cutting at the treated region, at various times ranging from a few days to several weeks. Lanolin pastes were also applied directly to the base or special regions of cuttings, but the method was found to be much less effective than the solution method.

The response of cuttings to successful treatments consisted in much earlier rooting, more roots, a larger root system, growth of roots from the stem tissue above the base as well as at the base of the cutting, and a close relationship between rooting response, concentration of hormone and duration of the period of treatment.

It was soon found that optimum dosages varied for cuttings of different species, and that response varied with the physiological condition of the cuttings and the conditions under which the treatment was carried out and the cutting was rooted. Enormous interest was stimulated and many workers in various parts of the world proceeded to carry out tests and work out optimum dosages for different species, and improve methods of treating the cuttings for practical usage. It was found that, in general, cuttings of plant species and varieties which are normally easy to root from cuttings almost invariably respond well to hormone treatment ; the time taken to root is shortened and the number of roots produced is greatly increased. With cuttings taken from species and varieties which are moderately difficult to root, hormone treatment is also effective, in the majority of cases, in accelerating root formation, and in causing the production of more roots per cutting.

This achievement in itself represents a considerable advantage to the practical propagator, in enabling him to clear his propagating beds more quickly and deal with many more cuttings. With cuttings taken from species which are normally very difficult to root however, hormone treatment has seldom succeeded in increasing root formation to such an extent as to be of much use in practice ; rooting has usually remained poor with a very small percentage of the cuttings surviving. Hardwood cuttings of apple, pear, walnut and many other species of our most valuable horticultural plants fall into this category and the development of effective techniques for such plants remains an ideal of propagation research.

The various methods of treating cuttings is considered in the following part of this review, and in the table at the end of this book is appended a selected list of plants, which have been treated by various workers, with the main results of treatment.

II. THE TREATMENT OF CUTTINGS WITH SYNTHETIC GROWTH SUBSTANCES.

A. Important details.

In considering the practical treatment of cuttings with synthetic root-forming substances, it cannot be too strongly emphasized that this treatment should be regarded as a supplement, rather than as in any way a replacement, of the methods normally used by the propagator. The ease with which different varieties of plants can be multiplied by means of cuttings varies widely, and, especially with difficult types, careful consideration of factors such as the age and condition of the parent plant, the type and physiological condition of the cuttings selected, and the time at which the cuttings are taken may make all the difference between success and failure. Similarly after the cutting material has been selected and treated, careful attention must be paid to the method of planting, the rooting medium to be used and the environmental conditions of moisture, temperature and light during the rooting period. The art of propagation has been built up over centuries of painstaking work and study and many important details of technique worked out for the propagation of different species. For such details of the selection and care of cuttings of different species, the reader is referred to the work of Garner (1944), and the book by Kains and Maquesten (1943).

Perhaps, owing to undue publicity, sensational press articles and hasty commercialization, the layman and even the skilled nurseryman has sometimes been led to expect impossibilities from the use of root-forming hormones. This has had the effect of causing, in some cases, a relaxation in the carefulness with which the cuttings are selected and the care given them during the rooting period. With treated, as with untreated cuttings, every care should be exercised to keep the cutting fresh and healthy until the new roots have formed. Used in such a way, the growth substance treatment of cuttings is undoubtedly a powerful additional weapon in the nurseryman's armoury.

Another important detail, is to be sure that the hormone preparation used is active, as some of the substances are liable to lose much of their potency on long keeping. That the substance is indeed active, can easily be determined by testing its effect on some cuttings of a moderately easy-to-root species and comparing the time taken for root formation and the number of roots formed, with untreated control batches. In this connection, it might also be useful if manufacturers placed a stamp on their products, giving the date of preparation.

B. Methods of treating cuttings.

1. The Lanolin Paste Method.

Most of the synthetic root-forming substances are readily soluble in lanolin, so that it is easy to make a paste of the active compound by stirring it into molten fat and then allowing the mixture to cool. Pastes made in this way were much used in the early work with these substances, especially for producing adventitious roots on the stems of intact plants, and for studying other plant responses. For treatment of cuttings, lanolin pastes were tested by Cooper (1935), Hitchcock (1935), Hitchcock and Zimmerman (1936), Tincker (1936), van der Lek and Krijthe (1937) and Brase (1938), but as a practical method of treating cuttings it is now obsolete and has been replaced by more convenient and more effective methods.

2. The Dilute Solution Method.

Solutions of the growth substance to be used, are prepared by first dissolving it in a small quantity of 95 per cent. alcohol and then obtaining the required dilutions by addition of water ; or one of the many concentrated proprietary solutions on the market may be purchased and dilutions made according to the directions supplied by the manufacturers. Stock solutions are best kept in the dark or in dark-coloured bottles. Other solvents such as acetone, ethylene glycol-mono-ethyl ether or ethylene-glycol-mono-methyl ether are also sometimes used.

The actual treatment of the cuttings simply consists in standing them to a depth of about one inch for some hours in solutions of appropriate concentration. After treatment, the ends of the cuttings are rinsed with water and they are then set in the rooting medium in the usual manner. This was the method used by Hitchcock and Zimmerman (1936) and Cooper (1936) and has been used by very many investigators since that time ; details of the treatment, time of immersion and substances and concentrations that have proved successful for different species and varieties of cuttings, can be found in the table of results.

In general practice a standard 24 hour treatment period is usual, and the concentration of the solution is adjusted to the requirements of the cuttings being treated. Correct dosages vary with the plant species, with the type of material selected for cuttings and with the growth substance used. The highest non-toxic concentration usually gives the best results.

Although the method is seemingly simple, there are several factors which must be carefully considered, if the best results are to be obtained. Thus the amount of solution absorbed by the cuttings depends to a large extent on the rate of water loss by the cuttings. This rate, again, naturally depends on the temperature and humidity conditions during treatment, light intensity and the density with which the cuttings are packed in the container with the solution. Cuttings with large leaves are likely to absorb more solution than those with small leaves. The seemingly conflicting results sometimes found in the literature, with apparently identical treatments and comparable cutting material, are probably largely due to these variables, which make comparison difficult unless cuttings are treated under standard conditions. In treating leafy cuttings, it is usually best to place the cuttings in the shade or in sash-covered propagating frames during the immersion period, as it is easier to control the amount absorbed under high humidity conditions. Under high evaporation conditions, where the leaves are transpiring rapidly, over dosage and injury are very liable. In spite of these facts, however, the solution method, when carefully used, with optimal concentrations and time of immersion, has often proved successful with difficult rooting species, when other methods have failed.

3. Injection of Cuttings under Vacuum.

This is really just a variation of the ordinary solution absorption method. It was used by Butterfield and McClintock (1939) and Pratt (1940). The cuttings are stood in a solution of the growth substance and placed in a closed container such as a vacuum desiccator which is then evacuated by means of a suction pump. The air is thus drawn out of the cuttings and the hormone solution is drawn in. This method has not, however, proved greatly superior to the usual solution method and has not succeeded with hardwood cuttings of plants such as apples, pears and plums, which are normally difficult to root. The special apparatus required makes the method useless to the practical propagator, especially as its advantages are not very marked.

4. The Dust Method.

The dust method used by Grace (1937) and later by very many other workers, has been found to be quite effective with cuttings of a number of different species. In some cases the dust has been prepared by merely grinding the active chemical to a fine powder and then thoroughly mixing it with the dust carrier by shaking. Talc or powdered charcoal have been the favourite carriers. Stoutemyer (1939a) prepared dusts by dissolving the hormone in 95 per cent. alcohol and then stirring this solution into the talc carrier to make a smooth paste. The paste was then dried in the dark using an electric fan, and stirred occasionally with a glass rod during the drying period. He claimed that in this way, a powder entirely free from lumps was obtained. The dry dust was then stored in glass containers in a cool place in the dark. Dusts containing from 2 to 8 mg. of indolylbutyric acid per gram are effective for many species.

The treatment consists simply in dipping the basal ends of the cuttings into the dust to the depth of about 1 inch, and then removing excess powder by light shaking or tapping on the edge of the container. The success of the method depends to a large extent on the right amount of dust adhering to the cutting ; if the cuttings are too wet excessive dosage may result in toxicity, whereas if the cuttings are too dry, insufficient will remain on them. Swartley and Chadwick (1939) in extensive studies with the dust method considered that the fineness of the talc carrier and the method of mixing with the hormone made little difference to the results obtained. They concluded, however, that moistening the base of the cutting before dipping into the powder was important. Dipping in alcohol instead of water before applying the dust was also tried but was not found to be superior. Hitchcock and Zimmerman (1939b), however, considered that the physical characteristics of the talc used, especially its fineness, made a considerable difference to the effectiveness of a preparation. Thus they concluded that a given concentration of growth substance may give a variety of results depending on what kind of talc is used, how it is prepared and how long and vigorously it has been ground, if prepared by the shaking procedure. Stoutemyer (1939a) also considered the fineness of the talc an important factor.

Many people will find it more convenient to use one of the ready made commercial talc-growth substance mixtures. There are many different brands on the market in different concentrations for different purposes, and recommendations for use are supplied. These preparations have given as good results as obtained by laboratory prepared mixtures in many cases. (Poesch (1938), Tincker (1938).)

There is some difference of opinion as regards the stability of the dust mixtures. Stoutemyer (1941) and Cooper (1944) found that talc preparations gradually lost their effectiveness, especially in moist air, even when stored in stoppered glass bottles. Kirkpatrick (1940a) on the other hand reported that one-year-old preparations, which had been kept in the greenhouse and used continually, were still as effective as freshly prepared powders. To be on the safe side therefore, it would appear best to store the powders in glass stoppered bottles in a dry place in the dark. The disappointing results sometimes obtained by practical nurserymen and amateurs may sometimes be due to the use of old powders, which have lost a good deal of their potency.

After dipping in the powder the cuttings are planted directly, taking care not to rub the dust off during insertion. In planting, a hole of appropriate size can first be made in the rooting medium with a knife or small stick and the medium then carefully firmed around the cutting. The chief advantage of the dust treatment lies in the fact that the cuttings may be planted immediately after treatment, thus saving a great deal of time. Moreover, it is claimed that the dusts have a greater latitude of dosage than solutions, and therefore not so many different concentrations are needed for different species. Furthermore, the amount of hormone applied to the cutting is more or less constant and does not depend on the environmental and other conditions during the absorption period, as is the case with the solution method. The dust method is certainly quite effective in hastening the rooting of fairly readily rooting species. Williams (1943) also found that roots formed on dust treated cuttings were longer, more numerous and with more branches than those obtained by the solution method.

It is best not to dip the cuttings in the bulk supply of dust, but to pour into another small container sufficient for immediate needs, and discard any of this that remains, rather than pour it back with the unused supply. In this way the possibility of any contamination with oxidizing enzymes or other substances or organisms from the cuttings, which might lead to a quicker deterioration of the stock supply is avoided.

5. The Method of Dipping in Concentrated Solutions.

Hitchcock and Zimmerman (1939b) suggested that concentrated solutions might also be used as a quick method for treating cuttings. The method consisted merely in dipping the base of the cuttings for a few seconds in a 50 per cent. alcohol solution, containing 1 to 20 mg. per litre of the active substance, before planting. Difficult rooting species such as apple, hemlock and rhododendron were said to respond well to such treatments. Cooper (1944b) made a detailed investigation of the method, using cuttings of derris, lonchocarpus, cinchona and cacao and was much impressed by the effectiveness and convenience of the method.

The solutions were prepared in the usual way by dissolving the hormone in 95 per cent. alcohol and then diluting with water or alcohol until the desired concentration was obtained. The basal ends of the cuttings were dipped in the solutions, and they were then set directly in the propagating medium. Cooper studied the effect of the concentration of alcohol in the solution and concentrations from 5 per cent. to 95 per cent. were found to have little effect on the rooting response obtained. The length of time during which the end of the cutting was immersed was also varied and times from 1 to 30 seconds appeared to have little influence on the effectiveness of the treatment. The standard procedure was to use a solution containing 50 per cent. alcohol, and to dip for 5 seconds.

The method, in addition to being more rapid than the dilute solution method, like the dust method, is not liable to so many variable factors during the absorption period, and in fact it also probably has a slight advantage over the dust method from the point of view of uniformity of dosage. It is however slightly more wasteful of hormone, and only sufficient solution for the daily requirement should be used at one time, but this solution can be continually used by fresh cuttings over this period. Used solution should not, however, be returned to the stock but discarded ; if this precaution is taken, stock solutions will keep for a considerable time. To obtain approximately equal rooting by this method requires roughly 25 times the concentration used in the dilute solution absorption method.

More recent information on the dip technique of treating cuttings confirms the fact that it has qualities which appeal strongly to the propagator. Hatcher and Garner (1948a and b) describe how this method has been developed in an intensive research programme which concerns the cutting method in relation to rootstock varieties, and report that the concentrations of the hormone dip found optimal by them are considerably lower than those previously recommended.

Doak and Greenwood (1947) also prefer the quick dip method to the talc dust method, although they consider that the dry method may be slightly more convenient for the ordinary grower.

6. Spraying the Stock Plant.

A method studied by Stoutemyer and O'Rourke (1945) consisted in spraying the mother plant with a synthetic hormone solution and then, subsequently, taking cuttings from it for the purpose of propagation. The hormones used were 2,4,5,-trichlorophenoxyacetic acid or its sodium salts, as these are cheaper and likely to be more effective for this method than the usual indolylbutyric or α-naphthaleneacetic acids used in the other methods.

The chemicals were first dissolved in a small amount of ethyl alcohol (never more than 1 per cent. of the final solution) and were then diluted with water. The sodium salt is slowly soluble in water alone, so that with it alcohol was not necessary. One gram of sodium lauryl sulphate was added to each litre of the spray solution, as a wetting agent and spreader.

The actual spraying of the foliage of the mother plant was carried out when the air temperature was above 70° Fahrenheit, usually about mid-day or in the afternoon. Morning spraying was avoided, on account of dew.

The cuttings were taken from the treated plants from 9 to 40 days after the spraying and were set in washed river sand, with bottom heat, and in some cases the air above the cuttings was kept moist by automatic humidification.

Good results were obtained with cuttings of *Buxus sempervirens* var. Handsworthii (K. Koch), using a spray of 25 mg. per litre, *Ilex crenata* var. *convexa* Mak., 100 mg./l. *Ilex vomitoria* Ait., 50 and 100 mg./l. *Ligustrum amurense* Carr., 10 and 20 mg./l. and *Ligustrum ibolium* Coe, 100 mg./l.

The experiments were of a preliminary nature but indicated that if plants were sprayed with 2,4,5-trichlorophenoxyacetic acid or its sodium salt, at a suitable concentration, the cuttings taken from such plants after a certain interval show essentially the same rooting responses as do cuttings treated by the more usual methods. More work needs to be carried out to determine optimal dosages for various species, and to fix the best time interval between spraying and taking the cuttings. It appears that the effect gradually diminishes with time, and the concentration of the spray will probably have to be adjusted for different environmental conditions and the physiological state of the mother plant when sprayed.

Garner and Hatcher (1944) sprayed plum rootstock layer beds with hormone sprays, with the idea of promoting rooting, but the results were not promising. Yeates (1947) sprayed *Coleus* plants with weak solutions of 2-methyl-4-chloro-phenoxyacetic acid and subsequently took cuttings at various intervals after spraying. Rooting was more rapid but growth was checked and later cuttings from unsprayed plants were more advanced.

7. Other Methods of Minor Importance.

Tincker (1936 and 1938) sprayed cuttings in the propagating beds, at intervals, with dilute hormone solutions. Tests with *Arbutus unedo* and *Eucalyptus coccifera* cuttings were unsuccessful. Hildreth and Mitchell (1939) however, reported successful results with several species by applying sprays in this manner. Tincker (1936) also found watering the rooting medium with hormone solutions to be successful in some cases but considered the method wasteful. The same author also immersed the leaves, instead of the bases of the cuttings, but the method did not prove satisfactory.

Evenari and Konis (1938) inserted crystals of the pure hormones into the bases of the shoots but the method did not appear to have any particular advantage and was rather liable to cause damage to the cuttings.

Swarbrick (1944d) obtained good results by dipping Yellow Egg Pershore suckers in a clay puddle impregnated with a 20 p.p.m. solution of either indolylbutyric acid or α-naphthaleneacetic acid. Not only were larger stands of living stocks obtained than from untreated suckers, but there was also a marked improvement in the growth of leader shoots in those treated with indolylbutyric acid.

8. Retreatment with Growth Substances.

Cooper and Went (1938) found that cuttings which have not rooted when removed from the rooting medium may sometimes respond to a second treatment. Cuttings of papaya, camellia and sweet orange were examples of species which were often induced to root in this way. Kordes (1943) also found retreatment beneficial in the propagation of evergreens and conifers by cuttings.

9. Manipulative Treatment of Cuttings.

Holly cuttings which had been left to callus over a period of 76 days were found by Stuart and Marth (1938) to root within a further 21 days when treated with hormones. No initial hormone treatment was given. Stoutemyer, Jester and O'Rourke (1940) working with cuttings of the black locust recommended storing the cuttings for a period at 70° F., following a treatment with either indolylacetic acid or α-naphthaleneacetic acid, in order to allow the root primordia to develop under favourable conditions. With hardwood cuttings, this treatment was especially successful when the cuttings were to be planted directly into soil in the open. A take of 69 per cent. was obtained in successful field plantings, by this method, and under greenhouse conditions, 90 per cent. rooting was no exception.

Amlong and Naundorf (1938) and Stuart and Marth (1938) found that wounding or splitting the bark at the base of the cutting before treatment sometimes gave additional response and more roots. Whether this effect is entirely due to greater absorption of the solution applied, or also to some physiological response of the cuttings to wounding is still a debatable point.

C. Choice of the substance to use.

1. Activity of Different Synthetic Growth Substances.

Comparison of the activity of the various synthetic growth substances used for promoting root formation in cuttings is considerably complicated by the fact that response varies with the species of plant used and also apparently, to some extent, with the physiological state of the cuttings and the medium used for rooting. The substances most generally in use for rooting cuttings are still β-indolylacetic acid, β-indolylbutyric acid, α-naphthaleneacetic acid and α-naphthaleneacetamide. Indolylbutyric acid is agreed by most experimenters to have some distinct advantages, in that it appears to be more effective than indolylacetic acid for a large number of species and in addition, to have a wider range of effectiveness without causing damage to the cuttings than α-naphthaleneacetic acid. Alpha-naphthaleneacetamide has not been so widely tested as the other three substances, but has been found quite effective in some cases.

Poesch (1938) found indolylacetic acid more effective than indolylbutyric acid for rooting cuttings of *Pyracantha coccinea* and *Lonicera korolkovii*, while Marques de Almeida (1940) considered indolylacetic acid better than α-naphthaleneacetic acid for orange cuttings. Griffith (1940) using cuttings of Douglas fir and Sitka spruce found indolylbutyric acid to be more effective than either indolylacetic acid or α-naphthaleneacetic acid, and Reano (1940) found indolylbutyric and indolylacetic acids to be much more effective than either indolylpropionic acid or phenylacetic acid for rooting coffee cuttings. For citrus cuttings, Cooper (1940) found indolylbutyric acid and indolylacetic acid to be much more effective than either α-naphthaleneacetic acid or α-naphthaleneacetamide for numerous varieties. Kordes (1942) found indolylbutyric acid superior to indolylacetic acid for rooting cuttings of the European grape. Kirkpatrick (1940b) also found indolylbutyric acid more effective than either α-naphthaleneacetic acid or indolylacetic acid for rooting rose cuttings, and McElwee (1941), working with cuttings of several species and varieties of ornamental plants, considered indolylbutyric acid to give better results than most of the other hormones in general use. Marth and Hamner (1943) using root cuttings of *Taraxacum kok-saghyz* obtained better responses using indolylbutyric acid or α-naphthaleneacetic acid than with either α-naphthaleneacetamide, β-naphthoxyacetic acid or a mixture of equal parts of the four substances. This held good whether the treatment was applied either by the dust or the dilute solution method.

Tajima (1939) rather surprisingly found phenylacetic acid superior to indolylacetic acid for rooting cuttings of *Pyracantha coccinea*. Hitchcock and Zimmerman (1939) and Kirkpatrick

(1939) have found α-naphthaleneacetic acid to be superior to indolylbutyric acid for cuttings of some species.

Doran and Bailey (1943b) working with cuttings of the blueberry *Vaccinium corymbosum* L. (Rubel variety) and using indolylbutyric acid, α-naphthaleneacetic acid, α-naphthaleneacetamide, indolylpropionic acid and several proprietary hormone preparations, found that the substance giving the best results depended to some extent on the physiological condition of the cuttings and the rooting medium used.

In comparing the activity of different substances therefore, not only the type of plant material used, but also its inherent properties and also the conditions under which the test is carried out must be considered.

Another possible variable is the potency of a particular sample of any of the substances being tested. For example, Koberidge (1940) compared the activity of two samples of indolylacetic acid, one of which was prepared locally and the other imported from the United States. While the imported product was superior for rooting cuttings of *Morus alba* and *Olea europaea*, both were equally effective for two species of *Populus*, and for cuttings of *Nerium oleander* the local product appeared to be superior.

It is, however, fairly clear that the general consensus of opinion favours indolylbutyric acid as the all purpose root-forming substance. It has a fairly wide range of effectiveness without causing toxic symptoms ; it is effective with cuttings of many different species and the root system formed under its influence is fibrous and well branched, thus rendering transplantation from the propagation bed easy. In cases where a good response cannot be obtained to this acid at appropriate concentrations, it is well worth trying some of the other root-forming substances. One disadvantage of α-naphthaleneacetic acid is its much narrower range of effectiveness and its liability to cause injury to the plant material at concentrations just above the optimum. Indolylacetic acid suffers from the fact that it is not quite so stable and is liable to deterioration, in fact reported cases of failure to obtain a response with this substance may sometimes be due to loss of activity of the preparation used.

Apart from these substances in general use there are numerous other substances now known to have root-forming properties.

Grace (1939e) tested the activity of a number of naphthalene acids and found that activity existed up to and including naphthalene hexoic acid. Acids with an even number of carbon atoms in the side chain were more active than those with an odd number.

In a later paper Grace (1940c) found naphthalenebutyric acid and potassium naphthalene hexoate about as active as indolylbutyric acid or naphthaleneacetic acid ; he advised practical propagators (Grace, 1945a) however to confine their interest to the more readily available indolylbutyric acid or α-naphthaleneacetic acid. Stoutemyer (1943) found that the substitution of the CH_3 group in various positions in the ring or the addition of H to form the tetrahydro compound with α-naphthaleneacetic acid, did not interfere with its action as a root-inducing substance and in fact might augment it in some cases. The marked differences in response of cuttings of different plant species to different root promoting substances was again strongly brought out in this work. In a later communication Stoutemyer (1944) discussed the differences in root-forming activities of α-naphthaleneacetic acid, α-naphthalene-α-propionic acid, α-naphthalene-β-propionic acid, 1-naphthalene-α-butyric acid, naphthalene-γ-butyric acid and the isoprene ester of naphthalenebutyric acid. With most of the species tested both the propionic acids were less effective than α-naphthaleneacetic acid, cuttings of *Pachysandra terminalis* were, however, an exception. Naphthalene-γ-butyric acid did not equal naphthaleneacetic acid in effectiveness, unless much higher concentrations were used. Naphthalenebutyric acid was highly effective and rather less toxic at doses above the optimum, than naphthaleneacetic acid. Stoutemyer again stresses the importance of comparing the activities of various root-forming substances with reference to specific species of plants and instances the fact that hardwood cuttings of the black locust, *Robinia pseudacacia*, are rooted much better with indolylacetic acid than with indolylbutyric acid. The isoprene ester of naphthalenebutyric acid was found to be considerably superior to the free acid for rooting cuttings of *Ilex crenata* var. *convexa*. Tincker (1940) found 3,4,-dihydro-1-naphthaleneacetic acid and 1,2,3,4 tetrahydronaphthalene-1-acetic acid as active as α-naphthaleneacetic acid. Cis- and trans-

1,2,3,4 tetrahydronaphthylidene-1-acetic acid were also tested. The cis compound was very highly active and gave very good results, but the trans compound was much less active.

Hitchcock and Zimmerman (1942b) compared the root-inducing properties of a whole series of phenoxy compounds with that of indolylbutyric acid and α-naphthaleneacetic acid. Both the dust and the solution methods were used and cuttings of several species of horticultural plants were employed as test objects. These included among others ; *Ardisia japonica* Thunb., *Rhododendron arborescens* Torr, *Celastrus scandens* L., *Cotoneaster apiculata* Rehd. and Wils., *Euonymus radicans* Sieb., *Hedera helix* L., *Ligustrum ovalifolium* Hassk., and *Lycopersicum esculentum* Mill. It was found that monohalogen substituted acids were less active than indolylbutyric acid or α-naphthaleneacetic acid, while 2,4-dichloro and dibromophenoxyacetic acids were about equal to them in activity and the corresponding α-propionic and α-butyric homologues had a much greater activity. Using cuttings of *Euonymus*, the descending order of activity for monosubstituted phenoxyacetic acids was : para > ortho > meta ; Cl > I at the ortho position Cl > NH_2 > NO_2 at the meta position ; and Cl > Br > NH_2 at the para position. Mixtures of three dichlorophenoxy homologues or of dichlorophenoxyacetic acid and either or both indolylbutyric acid and α-naphthaleneacetic acids were more effective than the individual compounds. The ratio of the different compounds in the mixture was, however, an important factor.

It was considered, however, that possible practical uses of the phenoxy compounds, for rooting cuttings of horticultural varieties, required more knowledge. One of the disadvantages of these compounds appeared to be that the most active of them had a very narrow effective range, below which it is either toxic, or causes undesirable effects such as swelling, proliferation, retarded growth of roots and noticeably fasciated roots. Results with solution and dust mixtures consisting of 1 part of 2,4,-dichlorophenoxyacetic acid to 3 parts of either or both indolylbutyric and α-naphthaleneacetic acids were favourable, and seemed to indicate that some of the most active phenoxy compounds might prove to be most useful in this way. The root system thus induced seemed of much better quality than when a phenoxy compound was used alone.

Zimmerman, Hitchcock and Harvill (1944) tested the root-forming qualities of a number of xylenoxy acids. These were not such active root formers as 2,4,-dichlorophenoxyacetic acid. Used at a concentration of 3·2 mg. per litre of water 2,5-xylenoxypropionic acid and 2,5-xylenoxybutyric acid were about equal in effectiveness to 2,4-dichlorophenoxyacetic acid, when tested on tomato leaf cuttings. The 3·4-xylenoxy group were only feebly active and considerably less so than the 2,4-xylenoxy group.

Hitchcock and Zimmerman (1945) using cuttings of privet (*Ligustrum ovalifolium* Hassk.) as the test object, again experimented with a large number of phenoxy compounds, including many of the compounds previously tested by the same authors (1942b) and also a number of new compounds. The tests were carried out using the solution method with a standard immersion time of twenty hours after which the cuttings were set in sand for rooting. The results were analysed statistically and the substances were grouped according to their activity. Phenoxy compounds which induced a relatively large number of roots over a fairly wide range of concentration and had an activity comparable to that of α-naphthaleneacetic acid or indolylbutyric acid were as follows :—

α-(2,4,5-Trichlorophenoxy)-propionic acid.
α-(2,4-Dichlorophenoxy)-propionic acid.
α-(3-Chlorophenoxy)-n-butyric acid.
α-(2,4-Dibromophenoxy)-propionic acid.
2,4,5-Trichlorophenoxyacetic acid.
α-(2-Chlorophenoxy)-n-butyric acid.

Many other phenoxy compounds tested were of a lower order of activity and from all standpoints it was considered that few of the compounds were as satisfactory as indolylbutyric acid or α-naphthaleneacetic acid. A distinct disadvantage of the phenoxy acids seemed to be their tendency to cause damage to the cuttings and the formation of abnormally thickened roots.

2. Mixtures of Growth Substances.

Went and Thimann (1937) found a combination of natural auxin and indolylacetic acid to produce more roots on etiolated stems of pea seedlings than either alone, while Amlong and Naundorf (1938) found that a combined solution of N/2,000 indolylacetic acid and N/2,000 α-naphthaleneacetic acid caused the production of a greater number of roots on *Tradescantia* cuttings than either of these substances used alone at a strength of N/1,000. A most effective mixture for inducing root formation in *Tradescantia*, was said to be N/2,000 indolylacetic acid + N/2,000 α-naphthaleneacetic acid + 0·02 per cent of yeast extract + 0·02 per cent. of magnesium nitrate + 0·02 per cent of manganese chloride.

Hitchcock and Zimmerman (1940) compared the root-inducing activity of two or more substances with the activity of each substance used alone, both by the solution method and the talc dust method. For cuttings of some species of plants the mixtures were more effective than any of the individual substances. Using talc dust preparations, for example, mixtures of equal parts of indolylbutyric acid and α-naphthaleneacetic acid, to give a total concentration of 4 mg. per gram, induced more uniform rooting, a higher percentage of rooted cuttings and a greater number of roots per cutting, in cuttings of *Celastrus*, *Thuja* and *Sequoia* than either of the substances used alone at the same concentration, but cuttings of other species such as *Picea* sp. and paeony (*Paeonia suffruticosa*) did not react in the same way. It was however, interesting and encouraging to note that mixtures of indolylbutyric acid and α-naphthaleneacetic acid were also often effective with cuttings of species of plants which normally only react well to one but not to both of these substances when used separately. Adding vitamins B_1 and B_6 to the hormone mixture also sometimes resulted in increased root formation. Hitchcock and Zimmerman (1942), when investigating the root-forming activity of phenoxy compounds, also found mixtures of dichlorophenoxyacetic acid with either or both indolylbutyric acid and α-naphthaleneacetic acid to be more effective than the individual compounds used alone for rooting cuttings of a number of species of plants.

Although cuttings of different species of plants undoubtedly react differently to different root-forming substances, the fact that mixtures are often more effective than individual substances used alone seems to hold out the attractive possibility of developing a universal or general purpose mixture for use in horticultural propagation.

3. Other Substances Aiding Root Formation.

(a) *Vitamins.*

Went, Bonner and Warner (1938) called attention to the fact that vitamin B_1 may have some effect on root formation in cuttings. Leafy lemon cuttings were treated with indolylacetic acid (200 mg. per litre) and then set for one week in sand. The cuttings were then divided into two groups and one series was placed for 24 hours in water while the other series was treated for a similar time with aneurine (vitamin B_1) solution (1 mg. per litre). All the cuttings were then replaced in the sand ; thirteen days later the water-treated cuttings had on the average 8·1 roots per cutting, the aneurine treated ones 16·3 roots per cutting while entirely untreated control cuttings averaged only 0·3 roots per cutting. Even bigger differences were obtained with leafy camellia cuttings, and these workers therefore concluded that vitamin B_1, if applied at the appropriate time after the formation of root initials under the influence of the hormone treatment, might greatly increase root development and growth of the cuttings. Warner and Went (1939) also cited favourable results with cuttings of several other species following retreatment with vitamin B_1, or with vitamin B_1 and peptone.

Tincker and Unwin (1939) however, found that Vitamin B_1, used alone did not induce root formation in cuttings, but thought that used in conjunction with the hormone treatment it might cause a slightly increased root growth, and Pearse (1939a) using softwood cuttings of deciduous fruit trees was unable to increase the percentage of cuttings rooting by applying a delayed vitamin B_1 treatment. Hitchcock and Zimmerman (1941) also reported that the application of vitamin B_1 either directly to the rooting medium or as a deferred treatment to the basal ends of the cuttings did not function as an activator to a treatment with indolylbutyric acid. McElwee (1941) also found vitamin B_1, used alone or as a supplementary treatment, to have little or no effect on the rooting of cuttings of several ornamental plants. Shrive (1940) however, suggested that vitamin B_1 although having no direct effect on root formation might be useful as a stimulant to the subsequent growth of slow-growing cuttings. Chadwick and Swartley (1940) also found vitamin B_1 to have little or no effect on root formation but favoured the view that it might stimulate the subsequent growth of root initials. Grace (1945a) using cuttings of *Physocarpus*, *Iresine* and *Lonicera* found that thiamine and nicotinic acid had no significant effect on the rooting response, while Kinoshita and Kasahara (1939) considered a combined treatment with indolylacetic acid and vitamin B_1 to be especially effective for rooting cuttings of *Thea*. Vitamin B_1 may perhaps be of some value in orchid propagation, for Curtis (1941) applying a solution of 1 mg. per litre at weekly intervals after an initial treatment with a a dust preparation of α-naphthaleneacetamide, obtained very satisfactory results.

The response, if any, to vitamin B_1 apparently varies with the conditions under which the test is carried out. Thus Haber and Swift (1940) found that watering the rooting medium (sand) with a solution of vitamin B_1 improved the percentage of cuttings rooting when temperatures are too low for optimum rooting. At more favourable temperatures for rooting, however, no such effect was found, and immersion of cuttings for 24 hours in a solution of vitamin B_1 at a concentration of 1 : 50,000 sometimes produced toxic effects.

Stoutemyer (1940) found that vitamin B_6 in concentrations of 0·1 to 0·2 p.p.m water applied to cuttings of 15 species of plants increased rooting in most cases, and in some instances this result was achieved independently of a treatment with growth substances. Leaf retention, by vitamin treated cuttings, was also said to be improved.

In general it appears that the response to vitamin treatment is too slight and too variable for it to be recommended in the practical treatment of cuttings. Apparently in most cases sufficient is either already present in the cuttings or can be synthesized, in the case of leafy cuttings, by the cutting itself.

(b) *Carbohydrates.*

Went and Thimann (1937a) found that treatment with dextrose or sucrose in conjunction with indolylacetic acid increased the number of roots formed on etiolated pea cuttings. The kind of sugar used was of importance, thus sucrose and fructose cause the production of more roots than dextrose. The length of the roots was also influenced, fructose producing the longest roots and dextrose the shortest. The possible presence of inhibiting substances in the sugar was also indicated by the fact that sucrose purified by ether extraction produced longer roots than untreated sugar.

The propagation of cutting material obtained from mother plants growing under normal light conditions presents quite a different problem, however, and in such cases it might reasonably be expected that sufficient carbohydrate reserves would be present to keep the cuttings alive until root formation had started. Leafy cutting material also undoubtedly carries on active assimilation of carbohydrates while in the propagating bed. Evenari and Konis (1938) however, using *Vitis* cuttings, claimed to have obtained a beneficial effect by applying sugar in addition to a hormone treatment. Grace (1939c) experimenting with dormant cuttings of *Lonicera tartarica* observed that treatment with a cane sugar solution as additional to a treatment with indolylacetic acid effected no further improvement in rooting and considered that dormant cuttings of this plant probably contained adequate carbohydrate reserves for optimal root formation. In a subsequent paper, however, Grace (1939d) using cuttings of two herbaceous and two woody plants found that treatments with cane sugar and ethyl mercuric phosphate slightly increased the response obtained with indolylacetic acid alone. Grace, Farrar and Hopkins (1940) also found a small, but significant favourable response to treatment with cane sugar, using Norway spruce cuttings. A beneficial response was noted too by Stoutemyer, Jester and O'Rourke (1940) who used a 2 per cent. sucrose solution as an addition to hormone treatment of leafless hardwood cuttings of black locust, both the percentage rooting and the subsequent growth of the cuttings being improved. McElwee (1941) also found a solution of sucrose (0·6 oz. to a quart of water) to have a considerable stimulating effect on root production in cuttings of several ornamental plants. In fact in some cases, where this solution was used alone, the response was said to have been almost as great as that obtained with indolylbutyric acid.

In connection with this question of carbohydrate supply to the cutting the work of Brandon (1939) is interesting. Cuttings of various species and varieties of the genus *Rosa* were examined and it was found that variation in starch content of the cuttings appeared to be mainly a genetically related phenomenon and bore very little relation to the facility in rooting. Glucose 1 per cent. was, however, found to increase the percentage of cuttings rooting in some few cases.

In general it may be said that with normal cutting material lack of sufficient carbohydrate is not usually a deciding factor in controlling root formation ; nevertheless in a few cases the addition of sugar has helped, to a limited extent.

(c) *Amino acids and nitrogen compounds.*

The fact that the nitrogen status of plant material has a considerable influence on its ability to regenerate roots has long been known, but was usually explained by its influence on the carbohydrate/nitrogen ratio. Goebel (1903, 1905 and 1908), Reid (1924a, b and c), Carleson (1929a), Starring (1924) and Schrader (1925). It is now generally recognized that this explanation is not entirely adequate, and furthermore supplying additional nitrogen to cutting material has been shown in some cases to have a considerable effect on the response obtained to root-forming substance. Went and Thimann (1937a) working with etiolated pea-stem cuttings found that amino acids, with the exception of tryptophane, do not promote root formation when applied to such cuttings : the action of tryptophane was considered also to be due, probably, to its conversion in the plant to indolylacetic acid.

Doak (1939a), however, using normal cuttings of *Rhododendron madderi* var. *jenkensii* found that a treatment with a mixture of amino-acids, in addition to a hormone treatment was a very effective additional stimulant to root formation. In one experiment, for example, all the cuttings receiving this treatment rooted after six weeks, during which time none of the cuttings treated with the hormone alone had rooted. The constitution of the amino acid mixture used was as follows :—5·0 mg. glutamic acid, 1·5 mg. lysine, 1·5 mg. histidine, 1·5 mg. phenylalanine, 0·015 mg. leucine, 0·0015 mg. isoleucine, 0·15 mg. valine, 0·05 mg. serine, and 0·5 mg. proline per litre of water. The basal ends of the cuttings were soaked in this solution for a week for the most effective results, but using a solution ten times as concentrated and an immersion time of 24 hours a considerable effect was obtained. In a subsequent paper, Doak (1940) using cuttings of the same plant, tested a number of nitrogen-containing compounds, both organic and inorganic, and found that all improved the rooting response of the cuttings to α-naphthaleneacetic acid. Among inorganic compounds, ammonium sulphate was rather more effective than sodium nitrate. Other nitrogenous substances used were adenine, guanine, xanthene, caffeine, uric acid, alloxan and betaine. No very definite relationship could be found, however, between the chemical structure of the nitrogenous compounds and the effectiveness of their action.

Thimann and Poutasse (1941) studied the rooting response of isolated leaves of *Phaseolus vulgaris*, and it was found that the survival of the cuttings was greatly improved by the presence of a small portion of stem tissue. Rooting was slightly depressed by a complete nutrient solution or by calcium or magnesium salts. Rooting was, however, strongly promoted by potassium nitrate, but was inhibited by ammonium sulphate even at high dilution. Of organic nitrogen compounds tested, adenine was the most effective while asparagine, guianine, choline and uracil were also effective to a lesser extent and yeast, nucleic acid and nicotinic acid showed slight, but variable effects. Pearse (1943) also found treatment with potassium nitrate beneficial in rooting single-bud cuttings of vines, following hormone treatment. The number of roots formed was slightly increased and root length was greatly increased by the treatment.

Overbeek, Gordon and Gregory (1946) using cuttings of the red hibiscus found that the root-forming action of the leaves can be entirely replaced by suitable amounts of sucrose and nitrogenous substances. Leafless cuttings, when hormone treated, formed very few roots, but if the cuttings were first soaked for 24 hours in solutions containing 10 mg. arginine per litre and 4 per cent. sucrose and then dipped in an alcoholic solution of indolylbutyric acid 2 mg. per ml. abundant roots were produced. Ammonium sulphate used at 1,000 mg. per litre in place of arginine was also quite effective.

The exact function of nitrogen compounds in promoting root formation still appears to be somewhat obscure, and is a subject which would seem to warrant further investigation. It is especially interesting in view of the fact that cuttings from nitrogen-starved plants usually root more readily than cuttings from well-nourished plants.

(d) *Mineral nutrients.*

Very little work has been carried out to investigate the use of nutrient solutions in conjunction with hormone treatments for promoting root formation in cuttings. This is perhaps not surprising, as it is well known by the practical nurseryman that a rich soil is about the worst possible medium for attempting to root most cuttings and under such conditions mortality rates are usually very high. Grace and Thistle (1939), however, found that weekly applications of a modified Hoagland's nutrient solution to the rooting medium in addition to an initial treatment with indolylacetic acid significantly increased the percentage of cuttings rooting, when using dormant cuttings of *Lonicera tartarica*. They suggest that cuttings may sometimes be deficient in minerals essential for rooting. The use of talc dusts containing nutrient salts in addition to growth hormones was also tested—Grace and Thistle (1940). This treatment, although producing no increase in the percentage of cuttings rooting, did sometimes result in a considerable increase in root growth and length of roots.

Poplaisky (1940) prepared cuttings from one-year-old shoots gathered during June and July from a number of different apple and pear hybrids, and, after removing the basal leaves, inserted the cuttings into oil-cloth bags containing sphagnum moss saturated with Knop's nutrient solution to which had also been added either a 10^{-4}N solution of potassium permanganate, a 0·0005 N solution of sulphanilic acid or a saturated aqueous solution of ethylene. Of the last three solutions the permanganate and the ethylene solution were the two most effective, and, depending on the variety from which the cuttings were taken, callus began to form in from 10 to 60 days from insertion. After planting out, the rooted cuttings were mulched and given a monthly watering with Knop's solution and potassium permanganate, replaced later by a nutrient solution consisting of ammonium nitrate and tricalcium phosphate. This treatment was claimed to increase the growth of the rooted cuttings considerably. Grace (1941) also found that potassium acid phosphate somewhat stimulated the rooting of softwood cuttings of *Deutzia*, *Symphoricarpus* and *Weigelia*, both when used alone or in combination with indolylacetic acid.

Amlong and Naundorf (1938a) found that the addition of yeast, magnesium nitrate and manganese chloride to indolylacetic acid solution resulted in increased root formation in *Tradescantia*.

(e) *Miscellaneous stimulants.*

(i) Acetic acid.

Small (1923) advocated the use of acetic acid as a stimulant for rooting cuttings. Experimenting with a large number of ornamental and greenhouse plants he found acetic acid to be very beneficial. He recommended the use of three teaspoonfuls of vinegar to a gallon of water. Laurie (1928) also found acetic acid beneficial in a number of tests.

(ii) Potassium permanganate.

Curtis (1918) found that cuttings treated with potassium permanganate for 24 hours, 5 days or continuously, showed a marked rooting response. He suggested several theories for this stimulation, e.g. a change in the nature of the food supply of the cutting, an effect on the rest period, a change in the balance of food supply between the tops and the roots in favour of the latter, a disinfectant action or an increase in respiratory activity by catalytically hastening oxidation. He considered that the last theory is the most probable explanation.

Knight (1926), however, working with cuttings of deciduous fruit trees, found no constant effect similar to that obtained by Curtis as the result of permanganate treatment. Chadwick (1929) using evergreen cuttings, found treatment with potassium permanganate to increase both the number and length of roots formed. The treatment consisted of either placing the cuttings in a solution of the substance for a number of hours or applying a solution (1 lb. to 50 gallons) directly to the rooting medium before planting. Laurie (1928) also found a 0·01 per cent. solution of permanganate a useful aid in rooting. Zschokke and Feurer (1927), however, treated apple and quince cuttings with hot water, ether and potassium permanganate, but failed to stimulate rooting. Winkler (1927) also found potassium permanganate to stimulate callus and root formation somewhat in vine cuttings. Brase (1938) working with deciduous fruit tree cuttings gave a treatment with 0·01 N potassium permanganate both before and after treatment with indolylbutyric acid, but found it did not increase the effectiveness of the hormone treatment.

(iii) Honey.

Oliver (1939) claimed that honey has a definitely stimulating effect on the rooting of cuttings of *Thuja occidentalis pyramidalis* and of chrysanthemum. The best treatment consisted in standing the cuttings in a 25 per cent. solution of honey for 24 hours before planting. A higher percentage of cuttings rooted, and there were more roots per cutting, moreover the response was only very slightly less pronounced than that which followed most favourable hormone treatment.

(iv) Methylene blue.

Blattný and Robek (1937) found that the application of a 1 : 1,000 solution of bacteriological methylene blue (tetramethyl-thioninchloride) free of zinc, for 30 minutes, stimulated the formation of roots and general growth of *Humulus lupulus* cuttings. Cuttings so treated produced roots four times as long and 31 per cent. heavier than those from untreated cuttings.

(v) Theelin.

Theelin has been stated by Went and Thimann (1937a) to increase the number of roots produced by auxin.

(vi) Dormancy-breaking substances.

Brandon (1939) found that treatments with ethylene chlorohydrin or thiourea depressed the rooting of rose cuttings slightly. Linder (1940) tested numerous organic and inorganic compounds including vitamins and dormancy-breaking substances on bud and root initiation in the horseradish root. Most of the substances exerted little or no influence.

(vii) Organic mercury compounds.

Grace (1940a) used ethyl mercuric phosphate in combination with indolylacetic acid in a talc dust for rooting Norway spruce cuttings. The organic mercury compound reduced root length, both when used alone or in combination with the hormone.

(viii) Various stimulants.

Traub (1938), using cuttings of *Passiflora quadrangularis* and *Bignonia*, compared the activity of many different substances in promoting root formation with that of a 0·02 per cent. solution of indolylbutyric acid. Tetra furfural alcohol (0·05 and 0·01 per cent. solution), calcium furoate (0·1 per cent. solution), nicotine (0·01 per cent.), sodium naphthol-4-sulphonate (0·01 per cent.), naphthalene tetrachloride (saturated solution in 0·5 per cent. alcohol), 1-proline (0·05 per cent.), anthracene (saturated solution in 0·5 per cent. alcohol), anthraquinone-β-sulphonic acid (0·01 per cent.) anthranilic acid (0·1 per cent.) and salicylidene acetamide ($\frac{1}{4}$ saturated solution) were found to have an activity equal to that of indolylbutyric acid solution, while many other substances showed activity to a lesser or greater degree.

(ix) Active substances from rooting cuttings.

Grace (1945b) found that physiologically active substances were liberated by rooting willow cuttings and retained by the solution or sand media, in which rooting had occurred. Root growth was stimulated in dormant cuttings by this substance but with non-dormant material it caused toxic effects. The substance was thermostable and appeared to exert effects similar to those caused by the synthetic plant growth substances. Salicylates were not responsible for the activity observed, but the active substance has not yet been isolated.

(x) Carbon dioxide.

Yeates (1947) working at the Massey Agricultural College, New Zealand, has found that supplying carnation cuttings (Otaki Pink) with additional carbon dioxide resulted in improved rooting. The cuttings received roughly three-quarters of full daylight intensity and the carbon dioxide concentration of the air was raised to approximately 2·5 per cent. at about 8.30 a.m. and 4.30 p.m. Other experiments have shown that additional advantages of carbon dioxide treatment are, (1) increased dry weight of cuttings, (2) additional stimulation of root formation above that obtained with hormone treatment alone. The same effect was not obtained by supplying sugar to the base of the cuttings, but the effect of sugar treatment was distinct from either that of carbon dioxide or growth substances.

In general it may be said that a large number of substances appear occasionally to stimulate root formation and root growth of easy rooting types of cuttings, but before such substances can be said to have a consistent effect on root formation they need to be thoroughly tested under a wide range of conditions and with many different species and varieties of plant material.

D. Special methods of encouraging root formation with growth substances.

1. Deciduous Fruit Tree Material.

Dostál (1942) found that treating apple (Cox's Reinette) cuttings obtained from mature trees by the usual methods failed to stimulate the formation of roots. If, however, a shoot was ringed and the exposed ring 1-1·5 cm. wide was wrapped around with filter paper the ends of which dipped into flasks containing a 0·0005 per cent. solution of indolylacetic acid, a healthy callus formation eventually appeared but no roots were formed. After wintering however, the shoots developed buds and roots.

Möhring (1943) described a method of inducing root formation on the scion varieties of tree fruits. With apple a ¾ inch strip of bark was scaled off the stems of one-year-old budded apple on Malling IX dwarfing rootstock and the wound was covered with Belvitan (containing indolylacetic acid) paste. The trees were then planted deeply. Root formation was satisfactory on the whole, but some varieties responded better than others. The treatment was particularly successful with Blenheim Orange, Allington Pippin, Winter Gold Pearmain and Ontario. Marcotting combined with growth substance application was also successful in some cases.

Sinha (1942) applied indolylbutyric acid in lanolin to the bases of layer shoots of plum (Pershore) and pear without obtaining any improvement in rooting. A slight improvement was obtained in the case of the plum rootstock Myrobolan B but this in any case roots fairly readily.

Swarbrick (1944d) obtained good results by dipping Yellow Egg Pershore suckers in a clay puddle impregnated with a 20 p.p.m. solution of either indolylbutyric acid or α-naphthaleneacetic acid. Not only were larger stands of living stocks obtained in both cases than from untreated suckers, but there was also a marked improvement in the growth of the leader shoots in response to the treatment with indolylbutyric acid.

2. Root Cuttings.

Marth and Hamner (1943) treated root pieces of *Taraxacum kok-saghyz* with indolylbutyric acid, α-naphthaleneacetic acid, α-naphthaleneacetamide and β-naphthoxyacetic acid. The water solution soaking method was used with an immersion time of 16 hours. Using a concentration of 50 mg. per litre the following rooting percentages were obtained, with indolylbutyric acid 87, with α-naphthaleneacetic acid 77, with β-naphthoxyacetic acid 73, with α-naphthaleneacetamide 70, while controls treated with water alone gave only 40 per cent. success. The roots induced by using indolylbutyric acid or β-naphthoxyacetic acid tended to be long and fibrous, whereas when α-naphthaleneacetic acid or α-naphthaleneacetamide were used the roots were short and thickened.

As regards the general treatment of root cuttings, however, it must be borne in mind that buds as well as roots must be regenerated, and in view of the well-known bud inhibiting effect of the growth substances careful treatment is required to ensure that adequate root formation is obtained without preventing the development of the buds.

3. Leaf Bud Cuttings.

Garner (1944) gives a clear description of the method of propagation by leaf bud cuttings. It is an especially useful way of obtaining a supply of valuable material quickly, as numerous cuttings can be obtained from one mother plant. The cutting consists simply of a single axillary bud, with leaf attached. Not very much attention has been paid to the hormone treatment of such cuttings, probably because of the difficulty of treating them without inhibiting the growth of the bud. Good results from treatments have, however, been obtained in some cases. For example Watkins (1940b) treated leaf bud cuttings of several species with a 5 mg. per gm. indolylbutyric acid and talc dust mixture, and was successful in several cases in producing a larger root system as the result of treatment, and the cuttings moreover, made satisfactory growth and developed into normal plants. Some species which gave satisfactory results were, *Bougainvillea spectabilis* var. Crimson Lake, *Cocculus laurifolius*, *Codiaeum variegatum*, *Hibiscus rosa-sinensis*, *Ipomoea fistulosa*, *Ixora coccinea* and *Thunbergia grandiflora* var. *alba*.

Williams (1943) also obtained successful rooting with leaf-bud cuttings of numerous species of broadleaved evergreens, treated with commercial hormone preparations, in both the dust (Rootone) and the liquid (Hormodin) form. These cuttings also made satisfactory growth after rooting. The cuttings were rooted in an acid peat and sand mixture in closed propagating cases, with bottom heat electrically supplied and thermostatically controlled at 80° F. The dust treatment was rather more satisfactory and gave a better root system than the solution soaking method.

Gorham and Landes (1945) did not find treatment with indolylbutyric acid, α-naphthalene-acetic acid, glucose, asparagine, glycine, *p*-aminobenzoic acid or potassium nitrate to improve root formation in leaf bud cuttings of *Taraxacum kok-saghyz* Rod.

4. Marcotting.

Several workers have reported the successful use of growth substances in stimulating the growth of roots of marcots.

Gossard (1942) working with the pecan, first wrapped the shoot to be marcotted with adhesive tape. After a few weeks this was removed and a toothpick impregnated with indolylbutyric acid was inserted at the point where roots should form, and this was then covered with the usual moist dressing. Abundant rooting resulted. Thakurta and Dutt (1941) also found that the application of 3 per cent. indolylacetic acid to the ringed portion of marcots of mangoes, when wrapping, and also to the base of a cutting 24 hours before severance from the mother plant, was very successful for rooting cuttings from young trees (2-3 years old). From older trees the results were not so successful. Cooper (1944a) also stated that a growth substance treatment could be used effectively in increasing the rooting of marcots of cacao and cinchona. The branches being marcotted were first girdled, and then the girdle and a small region above the girdle was painted with a solution containing 5 mg. per ml. of indolylbutyric acid in 50 per cent. alcohol. Moist sphagnum moss was used for wrapping the marcot. Up to 66 per cent. success was obtained with cacao and 100 per cent. with cinchona.

5. Special Care of Cuttings.

The first essential in rooting cuttings is to keep them healthy until the new roots can form, and this is just as important with hormone treated cuttings as with untreated ones, because, although rooting may take place more quickly, it must be remembered that the reserves in the cuttings are also likely to be used up more quickly. The greater the degree of control that can be exercised during the pre-rooting period therefore, the more consistent are likely to be the results obtained, if comparable cutting material is used. The results obtained by Stoutemyer and Close (1946) are important in this connection. Cuttings were rooted in an opaque building with propagating beds lighted by various types of fluorescent and cold cathode lamps. In this way the exact control of light quality, intensity and duration was made possible. It was found that satisfactory rooting could be obtained under relatively low light intensities and that radiation in the orange-red end of the spectrum favoured rooting. Cuttings treated with growth substances rooted well under these conditions and interaction with growth substances and photoperiod were observed. For example, cuttings of *Acalypha wilkesiana* var. *macrophylla* rooted more heavily under 16 hours daily illumination than under continuous lighting, but when treated with growth substances rooting was about the same under both photoperiods. Cuttings of rough lemon responded best to hormone treatment under continuous illumination, whereas cuttings of Chinotto orange responded best to treatment with a 16 hour photoperiod.

III. THE MECHANISM OF INDUCED ROOT-FORMATION

A. Evidence for the existence of specific internal factors controlling root-formation.

Cooper (1935, 1936), using lemon cuttings as the test material, observed that treatment at the base with a relatively strong solution of indolylacetic acid caused the localized formation of a great number of roots. When, however, the treated basal portions were cut off soon after treatment and the cuttings were then again treated, very few more roots were initiated than in an untreated cutting. He therefore suggested that other substances, already present in the cuttings, accumulated at the base under the influence of the original treatment with indolylacetic acid and were removed when that portion was cut off. In a later paper, Cooper (1938), using the *Avena* coleoptile test, estimated the amount of hormone present in cuttings after treatment. Portions of cuttings, some of which had been treated at the apex and some at the base with indolylacetic acid, showed large amounts of hormone present in the bark immediately after treatment, but about 90 per cent. of this disappeared during the first day. Very little hormone was recovered from the bark at the apex of cuttings, which had been treated at the base with 0·001, 0·005 and 0·02 per cent. indolylacetic acid. Moderate amounts of auxin were, however, recovered from the basal portions when the cuttings were treated at the apex with these solutions, though with the 0·02 per cent. solution the amount recovered at the base was small as compared with that at the apex. While approximately the same amounts of hormone could be recovered from treated apple (Delicious) and lemon (Eureka) cuttings, yet the lemon cuttings responded by increased root formation, while none of the apple cuttings produced roots. Cooper therefore concluded that apple cuttings are lacking in certain internal substances necessary for root formation, and concluded that with lemon cuttings the action of the basal treatment with indolylacetic acid is to cause the downward transport of a substance or substances which are essential for root formation and which thus become concentrated in the basal region of the cutting. A similar conclusion regarding the role of an internal factor in root formation was reached by Went (1938a) from experiments with etiolated pea cuttings. He found that if a cutting was divided into a number of sections and each section treated with a high concentration of indolylacetic acid, the total number of root primordia produced on these sections was about the same as on an intact cutting similarly treated. He therefore suggested that the number of roots produced is determined by internal substances which limit root production, even though applied hormone is present in excess. Most of the root initials were formed on sections some distance from the apex, and on this theory these must therefore have contained more of these substances.

When indolylacetic acid was applied to the apex of the uppermost one-eight of a cutting, only a few primordia were formed at the top. The treatment in this case therefore appeared to have mobilized some other substance or substances from the lower portion of the cutting.

Hellinga (1937), however, using *Coleus* cuttings found that a second treatment of cuttings at the new base, exposed by cutting off the originally treated base, caused the production of more roots when the cuttings were placed in sugar solutions and Pearse (1938a) using dormant willow cuttings treated with indolylbutyric acid obtained a similar result even without the presence of a sugar solution. Dorfmüller (1938) and Hitchcock and Zimmerman (1938) also carried out similar experiments with different species and obtained renewed root formation after a second treatment. These experiments did not, however show conclusively that the hormone applied is the major factor in controlling root formation, as the internal factor may be capable of renewed formation. For example Bouillenne and Bouillenne (1938) found that, when indolylacetic acid was applied to hypocotyls of *Impatiens balsamina* under carefully controlled conditions, it did not cause an increase in the number of roots formed over the number of those formed on control plants treated with solutions of sucrose containing varying amounts of glycine, alanine and vitamin B_1. The amino acids appeared to prolong somewhat the life of the hypocotyl. It was concluded that the indolylacetic acid did not increase the total potential number of roots but speeded up the process of formation, by mobilizing the internal factor (rhizocaline) and could only be effective when this factor was present in the tissues.

Dettweiler (1942) also considered that there is no proof that root formation and growth responses observed as the result of application of indolylacetic acid are caused by it directly. He considers that the evidence available can still be best explained by supposing that the indolylacetic acid merely activates the natural growth substances (auxins).

Indolylacetic acid paste was applied to the internodes of *Coleus* plants and to the inflorescence branches of *Tagetes patula*. Extracts of the treated plants were then prepared and the auxin and heteroauxin in these extracts were separated by making use of the fact that indolylacetic acid is destroyed by acidity, whereas auxin is destroyed by alkalinity. Using this technique he claimed to be able to show that treatment with indolylacetic acid soon induced a great increase in the production of auxin. The indolylacetic acid applied only penetrated into the tissues in small amounts and there stimulated production of auxin. There was also a considerable increase in auxin formation during and shortly before the emergence of lateral roots, whereas the quantity of indolylacetic acid present remained small and practically constant. It was therefore considered that the formation of lateral roots in the treated zone was the result of the accumulation of natural auxins. If the sugar content of the tissues and the auxin content of the plants were reduced to a low level, by keeping the plants in darkness for some time before treatment, the application of indolylacetic acid still caused almost as great a production of natural auxin as before. This increase therefore appeared to be independent of carbon assimilation. Experiments were also carried out in which the leaves were removed and also with isolated stem pieces, and these appeared to show that auxin accumulation was also independent of the presence of leaves or of the growing point. Indolylbutyric acid was also used and appeared to act in precisely the same manner as indolylacetic acid.

B. The influence of leaves and buds on the response to synthetic growth substances.

The influence of leaves in controlling the response of cuttings to applied growth substances was investigated by Rappaport (1940). Using material of *Skimmia foremanii*. Mast., cuttings were selected bearing six leaves each. From cuttings of different groups from 1 to 6 leaves were removed, and in each group there were three different series, the first being untreated, the second treated before removal of the leaves, and the third treated after removal of the leaves with indolylacetic acid solution (100 mg. per litre) for 18 hours, by the solution soaking method. The results showed that untreated cuttings with more leaves rooted better than those with fewer leaves. This was also true of the treated cuttings and it made little difference whether the treatment was applied before or after removal of the leaves. These experiments indicated therefore that the amount of applied hormone absorbed by the cuttings, which is presumably affected by the number of leaves on the cuttings during the absorption period, is only a factor of minor importance and that the major influence of the leaves on the rooting response could probably be ascribed to natural root-forming substances coming from the leaves.

Geiger-Huber (1940) also found that with cuttings of *Ligustrum vulgare* the removal of buds from the cuttings largely prevented root formation even when growth substances were applied, and O'Rourke (1942) found that the rooting of cuttings of blueberry which bore only leaf buds was much superior to that of cuttings carrying one or more fruit buds.

Probably the most conclusive piece of work yet carried out on the influence of internal factors in controlling root formation in cuttings is, however, that of Gregory and Overbeek (1945) and Overbeek and Gregory (1945). Working with two varieties of hibiscus, it was found that cuttings of the red variety root readily, whereas leafy cuttings of the white variety usually completely fail to form roots, only the thickest of hardwood cuttings producing a few roots sporadically. Using the quick dip method and a solution of indolylbutyric acid in 50 per cent. alcohol, abundant roots could be obtained on cuttings of the red variety, but the treatment had no effect on the rooting of the difficult cuttings of the white variety. Grafting an easy-rooting cutting of the red variety on to a cutting of the white variety, also failed completely to stimulate rooting in the latter. If, however a cutting of the red variety was grafted to one of the white variety and the base of the cutting of the white variety was then treated with the indolylbutyric acid solution abundant roots were formed. This indicated clearly that two separate factors were definitely essential for the rooting of the cuttings of the white variety, (1) the applied growth substance and (2) factors lacking in the white variety but supplied from the cutting of the red variety. It was therefore concluded, that the cuttings of the white hibiscus are difficult to root, not only because they are deficient in growth substance, but also because they are deficient in another factor or factors which normally comes from the leaves. When both these factors are provided roots are formed without difficulty.

Leafy cuttings of the white hibiscus are very prone to shed their leaves before rooting can take place and although attempts were made to retain the leaves by the application of hormone sprays these usually failed to achieve this object ; young tip cuttings which did, however, sometimes retain their leaves, also did not root readily. Attempts were also made to root detached leaves of both the red and the white variety and again it was found that while leaves from the red variety root readily, leaves from the white variety could not be induced to form roots. It therefore seemed fairly clear that the leaves of the white variety also have a lower effective content of the factor or factors necessary for root formation, even when growth substance is supplied.

Overbeek, Gordon and Gregory (1946) investigated more deeply the nature of this combined action of factors coming from the leaves and of applied growth substances. It was found firstly that light was not necessary for the action of the leaf to be exerted, for nearly as great an influence on root formation was obtained when cuttings were kept in the dark as in diffuse light. It was also found that the root forming action of the leaves can be entirely replaced by suitable amounts of combinations of sucrose and nitrogenous substances. An effective treatment consisted in soaking the cuttings for 24 hours in solutions containing 10 mg. of arginine per litre and 4 per cent. sucrose, followed by dipping in an alcoholic solution of indolylbutyric acid 2 mg. per ml. Ammonium sulphate used at 1,000 mg. per litre in place of arginine was also quite effective. A number of other nitrogen compounds were also tested but were less effective. It was therefore concluded that the main function of the leaves, in the process of root initiation, is to supply the cuttings with sugars and nitrogenous substances. That the leaves do actually supply such nutritional substances, even in the dark, was confirmed by quantitative chemical analysis. There therefore seems no further need to postulate the production of a special internal root forming substance such as " rhizocaline " in the leaves of the red hibiscus, but whether these results will prove to be of general application to other species remains to be seen. Yeates (1947) has carried out some preliminary tests with the application of sucrose, arginine and indolylbutyric acid to cuttings of azalea and daphne. Rooting was not improved.

C. Other factors and the response to applied growth substances.

With root or shoot cuttings which will regenerate roots easily, applied hormones are usually effective in increasing the number of roots formed, and provided the appropriate concentration can be maintained for a sufficient length of time, roots will be formed in any portion of such cuttings which contain meristematic cells or cells capable of becoming meristematic. The presence of buds or leaves is certainly not a necessary condition for root formation on root cuttings (Czaja 1935a and b, Stoughton and Plant 1938). More recently de Ropp (1947a) found that cultures on agar of small portions of sunflower stem tissue 4 mm. in length would produce roots in responses to hormones and indeed could be used as a delicate test for their presence. Lindner (1940), however, found that buds and roots in horseradish root pieces are initiated only in association with a lateral root trace, and Thimann and Poutasse (1940) found that the presence of a small piece of stem on single leaf cuttings of *Phaseolus* greatly stimulate root formation.

It has been suggested that failure to produce roots is sometimes due to enzymes which rapidly destroy the hormone applied, but Cooper (1939) was able to recover the active substances from treated apple cuttings in spite of failure to form roots.

Hardwood cuttings especially of difficult rooting types of plants have not generally responded very well to synthetic growth substance treatment. In some cases this may be due to exhaustion of the reserves originally present in the cuttings.

Cooper (1944) working with cuttings of *Derris elliptica* var. Sarawak Creeping and *Lonchocarpus utilis* found that, although treatment of cuttings bearing leaves was highly effective, treatment of leafless cuttings did not give such satisfactory results. Indolylbutyric acid, α-naphthaleneacetic acid and α-naphthaleneacetamide, applied by the quick alcohol dip method, were all effective in inducing root formation on leafless cuttings, but the roots often failed to grow and the mortality rate of the cuttings was increased. With *Derris* the roots only grew out a short distance and then withered and died and bud growth was considerably inhibited. With *Lonchocarpus* the same thing happened and in addition the cuttings were often attacked at the apex by moulds. Two possible explanations were put forward (1) that the quicker root formation in conjunction with bud inhibition caused a rapid depletion of reserves, which could not be replaced quickly enough as bud growth was inhibited, and (2) in *Lonchocarpus* a possible stimulation of mould growth by the growth substances themselves. In some cases supplementing the natural reserves by additional sugar is helpful as a practical treatment, but such cases are comparatively rare.

It is certainly clear that factors inherent in the plant tissues are important in governing the response to treatment with synthetic hormones. Thus numerous workers using widely different plants have found that increased root formation after treatment occurs only when the cuttings used are in a certain stage of growth. This optimal stage, however, varies widely, some species responding best when the cuttings are taken while in active growth, whereas others react best when growth is slowing down or has ceased. No general rule can therefore be given and the best material to use for different varieties and species of plants can only be found by experiment. There is still a large class of plants including many of the most important horticultural species and varieties which fail to respond to hormone treatment, in fact in the great majority of cases it appears that unless material shows some tendency to form roots without treatment, treatment with synthetic hormones is usually ineffective. The elucidation of the factors responsible for poor rooting in white hibiscus cuttings by Overbeek, Gordon and Gregory (1946) is very encouraging, however, and renews the hope that factors responsible for poor rooting in deciduous fruit cuttings and other valuable material will eventually be discovered, although it is highly probable that considerable variation will be found to exist in the factors lacking in different species.

D. Variation in the response obtained to different substances.

Many different substances not closely related chemically are active in promoting root formation, yet the particular substance used may have specific effects, for it has been pointed out by Oliver (1938), Hitchcock and Zimmerman (1938) and Pearse (1939a) that a qualitative difference exists in roots induced by indolylbutyric acid and α-naphthaleneacetic acid respectively. Went (1939a) used etiolated pea stems as quantitative test objects for the root-forming activity of different hormones and as a result of dividing the period of treatment into two shorter ones, considered that it was possible to distinguish two separate phases. He tentatively suggested that the first phase of the applied hormone action was a redistribution of " rhizocaline " within the stem ; this phase could be induced, not only by indolylacetic acid, but also by phenylacetic acid, γ-phenylbutyric acid, sodium naphthol sulphonate and other substances. The second phase he considered to be the activation of this accumulated " rhizocaline ", which can only be accomplished by indolylacetic acid and related substances.

Hitchcock and Zimmerman (1942b) have shown, too, that while some of the phenoxy compounds are very active root formers they have the practical disadvantage of causing the formation of abnormally thick and fasciated roots.

E. The condition of the mother plant as affecting the response of cuttings.

In normally growing plants it is well known that the cutting must be in a certain physiological condition, or, as the practical man would say, of the right degree of hardness, if the most successful rooting is to be obtained. This is also true in many cases for the best response to applied hormones. It is also well known that cutting material in a young or juvenile condition usually roots more readily than more mature material. Stoutemyer (1937) developed a method of obtaining juvenile material of apples. He found that shoots grown from adventitious buds, on a young active root, showed juvenile characteristics and that stem cuttings made from these shoots formed roots readily. Juvenile shoots can also sometimes be obtained from near the base of older trees. The age of the parent plant is important ; cuttings root best when taken from young shrubs and trees, and those taken from young trees root better than those taken from young shoots of old trees.

Cuttings from the youngest part of herbaceous plants at the tips of the shoots are also often the most successful.

It has already been noticed that nitrogen starved material often roots more readily than material obtained from plants receiving a full nutrition. Sinha and Vyvyan (1943) working with the plum rootstock Myrobalan B found that cuttings taken from a mature hedge rooted 80 per cent., from a layer bed 69 per cent., from budded layers 47 per cent. and from one-year-old rooted cuttings 28 per cent. Here again root competition and consequent nitrogen starvation of the material was probably a major factor. Pridham (1942) also found that the maturity and treatment of the stock plants exerted a considerable influence on the rooting and subsequent growth of cuttings of *Ligustrum ovalifolium* and *Rhododendron catawbiense*.

Cailloux (1943) grew five groups of tomato plants in pure quartz sand fed with nutrient solutions respectively adequate, containing three times the amount of nitrogen necessary, deficient in nitrogen, deficient in phosphorus and deficient in potassium. Rooting did not seem to be related to the starch content, since cuttings deficient in potassium rooted poorly but yet tended to accumulate starch. Pearse (1943) using cuttings of the vine *Vitis vinifera* also obtained material from plants growing in sand cultures, and found that cuttings from starved plants relatively low in nitrogen rooted best, and also responded to hormone treatment rather better than material from fully fed plants. In a later paper Pearse (in press) described experiments in which vine plants *Vitis vinifera* var. Waltham Cross and plum trees *Prunus cerasifera* × *P. munsoniana* var. *marianna* were grown in sand cultures receiving respectively, full nutrient solution, deficient in nitrogen, deficient in potassium, deficient in phosphorus, deficient in magnesium and deficient in calcium. The cuttings obtained from these plants varied in ease of rooting in the following order, from highest to lowest :—nitrogen deficient, full nutrient, potassium deficient, phosphorus deficient, magnesium deficient and calcium deficient. In other experiments cuttings were obtained from plants grown at five different levels of nitrogen and two levels of phosphorus giving ten different treatments in all. With this material it was found that the number of cuttings rooting and the number of roots formed increased as the nitrogen level of the parent plant was reduced to a low level, but still further reduction resulted in poorer rooting. Decreasing the phosphorus supply to the parent plant was detrimental to rooting, but the effect of the nitrogen level was still apparent even at a low phosphorus level.

In those groups of cuttings which rooted most easily, hormone treatment usually resulted in increased root formation, but the nutritional effect was predominant. The nitrogen nutrition of the parent plant in relation to root formation in cuttings and the response to growth substance treatment needs further investigation ; the fact that cuttings from potassium deficient plants, although high in carbohydrate reserves, react entirely differently from nitrogen starved material also high in such reserves is especially interesting.

F. The correlation between root and shoot formation.

Czaja (1935a and b) using root cuttings of *Taraxacum*, which very readily regenerate shoots at the apical end and roots at the basal end, found that if shoot formation was suppressed at the apical end of a cutting, by embedding this end in plaster of Paris, shoots and not roots were initiated at the basal end. This was also the case if shoot formation was suppressed by continually cutting slices from the apical end ; if, however, shoot formation was allowed to continue unhindered at the apical end, and a mica plate was inserted at right angles to the long axis of the cutting in the middle region of the cutting and extending half-way across, shoots were then formed on the semicircular area of the basal end directly beneath the mica plate, and roots on the adjoining semicircular area. The correlation between shoot formation at the apical end, and root formation at the basal end of the cutting was thus clearly shown. In a further experiment a paste containing indolylacetic acid was applied to the apical end, and this effectively suppressed shoot formation at this end while roots were produced at the basal end. Thus indolylacetic acid could replace the shoots in determining root formation at the basal end. Stoughton and Plant (1938) obtained similar results using root cuttings of seakale (*Crambe maritima*). The application of α-naphthaleneacetic acid at the apical end caused roots to form at both ends, but if a millimetre slice were removed every five days from both apical and basal ends for a period of 8 weeks, 25 per cent. of the cuttings subsequently produced shoots at both ends. They therefore concluded that the initial differentiation of meristematic tissue is determined, at least in part, by the local concentration of the hormone, shoots developing at lower and roots at higher concentrations.

Williams (1937) experimenting with *Selaginella* showed that the concentration of indolylacetic acid was a factor in determining whether an angle meristem developed into a rhizophore or as a leafy shoot. Howard (1938), working with seedlings of kale, *Brassica oleracea*, treated the stems of decapitated plants with pastes containing indolylacetic acid and found that adventitious roots were produced, but later adventitious shoots were also formed, and again when the supply of hormone was removed. Later still, when the new shoots had grown for some time, a second crop of adventitious roots was produced, presumably under the influence of the hormone supplied by the developing shoots themselves. Howard (1940), however, contradicted his former report that an initial could be converted into a root meristem under the influence of indolylacetic acid and thought the true explanation to be that an extra external meristem had been formed in the cotyledon axil above the axillary bud and that this meristem had grown into a root. Fischnich (1939) also considered that high concentrations of growth substance lead to root production, and that low concentrations favour shoot formation. Callus tissue, which would ordinarily form roots could be induced to form shoots by lowering the growth substance content by inverting the cutting or by removing portions of the bark. Lindner (1939) also found that relatively high concentrations of indolylacetic acid and of α-naphthaleneacetic acid inhibit shoot production and stimulate root production in portions of horseradish root.

Balansard and Pelissier (1942) treated detached leaves of *Begonia semperflorens*, *B. franconis*, *B. discolor* and *B. rex* by immersion for from 24 to 48 hours in a 1 : 10,000 solution of indolylacetic acid. The leaves were then placed in water and roots appeared after 11 to 12 days and somewhat later leaf buds were formed. Untreated leaves sprouted much later or not at all.

Went (1941c) studied the transport of auxin in inverted cuttings. He used cuttings of *Tagetes* and found that in cuttings which had been induced to form roots at the original apex and shoots near the base, the original polar auxin transport persisted, but that in addition a new auxin transport from the original base towards the apex developed. The first indication of this inverse transport occurred three weeks after growth had started in the inverted cutting, and after a month both normal and inverse auxin transportation occurred simultaneously in the inversely functioning portion of the stem.

G. Root origin and metabolic activity in response to treatment with synthetic growth substances.

1. Histological Responses of Stems to Growth Substances.

Kraus, Brown and Hamner (1936) decapitated young bean seedlings at the top of the second internode and applied a small amount of lanolin paste containing 30 mg. of indolylacetic acid per gram of lanolin to the cut surface. Controls were left untreated or treated with pure lanolin. Histological studies were made of material collected and preserved at 6 hour intervals up to a total period of 168 hours.

Several hours after application the epidermal cells enlarged slightly and divided in the radial plane, the cells of the cortical parenchyma enlarged and those near the endodermis became meristematic, starch and chloroplasts rapidly disappearing. The cells of the endodermis were highly responsive and active division was noted shortly after treatment. The derived cells differentiated as xylem and phloem elements and large, often multinucleate, parenchyma cells. Some remained actively dividing and others gave rise to adventitious roots. The cells of the pericycle proliferated slightly. The parenchyma of the primary phloem responded similarly to the endodermal cells, and the parenchyma of the secondary phloem also underwent marked proliferation.

Borthwick, Hamner and Parker (1937) decapitated young tomato seedlings above the second leaf and applied a mixture of 20 mg. of indolylacetic acid in 1 gm. of lanolin to the cut surface.

Control plants were excised in the same manner and were treated with lanolin only. The internode treated with indolylacetic acid enlarged at about the same rate as normal internodes below, but control ones failed to enlarge. After treatment the first result was an enlargement of the cells of the epidermis and cortex. Many of the tissues became meristematic, the zone of activity being almost entirely confined to a region 0·5 to 2 mm. from the treated surface. Nearly all the parenchymatous cells in this zone divided, the endodermal cells, the external and internal phloem parenchyma and the pith cells adjacent to the internal phloem exhibiting the greatest activity. The epidermis, most of the pericycle, sieve tubes and companion cells and internal fibres showed little or no meristematic activity. A ring of adventitious roots was formed around the stem as the result of divisions in the external phloem, and another ring of roots was formed near the pith from cells of the internal phloem and adjacent pith. Nitrates were more abundant in untreated stems, but the concentration of protein increased, especially in the areas where cell division was rapid, and starch disappeared from the cells. Reano (1940) gave detailed histological and microscopic observations on the response of stem-tip cuttings of coffee treated with indolylacetic acid, 4 to 5·6 mg. per 100 ml., and to other growth substances.

There are considerable differences in the histological responses obtained to different growth substances. Only a few details from the numerous papers can be mentioned here.

Blum (1941) described the responses of sunflower stems to phenylacetic acid and found no adventitious root formation. Whiting and Murray (1946) applied a 2 per cent. mixture of phenylacetic acid in lanolin to bean plants *Phaseolus vulgaris* var. Red Kidney, decapitated at the second internode. The histological responses included marked proliferation of the inner cortical parenchyma, endodermis and primary phloem parenchyma. The outer cortical parenchyma, the medullary rays and the peripheral pith showed little response. Root primordia were rarely formed and in this respect the action of phenylacetic acid differed from that of indolylacetic, indolylbutyric and naphthaleneacetic acids.

Tetra hydrofurfuryl butyrate caused intense activity in the xylem and α-naphthaleneacetamide induced heavy wall thickening and increases in secondary xylem.

Kraus (1941) studied the histological responses of bean plants to tryptophane and showed that the response obtained differed in many respects from that to indolylacetic acid.

Murray and Whiting (1946) also compared the effect of tryptophane with that of indolylacetic acid, over a wide range of concentration, with the object of determining if the effects of tryptophane could be explained by its conversion to indolylacetic acid in the plant.

At none of the concentrations used, however, was the response to indolylacetic acid exactly the same as that to tryptophane. There thus appeared to be a distinctive response to tryptophane which could not be explained by its conversion to indolylacetic acid.

Whiting and Murray (1946b) also studied the response of the second internode of decapitated bean plants to nicotine and considered that the response obtained resembled a wound response rather than the kind of response obtained with other growth substances.

Beal (1945) applied four substituted phenoxy compounds with 0·5 per cent. concentration of Carbowax 1500 and in lanolin to the bases of the leaves of bean seedlings. No roots developed in the second internode up to 20 days after treatment, but roots developed in abundance in the hypocotyl and in the first internode.

2. Histological Responses of Roots.

Borgström (1939a) investigated the effects of a number of growth substances on bulb forming plants (*Allium cepa*, *A. fistulosum* and *Crocus*) determining effective concentrations, toxicity limits and gross morphological effects. He found that elongation of roots was inhibited by treatment with all but the most dilute concentrations and inhibited elongation was often accompanied by enlargement of the root tips. Marmer (1937) reported excessive root-hair formation following treatment of wheat seedlings with indolylacetic acid, indolylbutyric acid and indolylpropionic acids at pH 4·6 but not at pH 7·5. Levan (1939) investigated the histological and cytological responses of roots of species of *Allium* to several chemicals and Bürström (1942a and b) discussed the morphological changes induced in roots of wheat following treatment with indolylacetic acid.

Carlton (1943) made an intensive histological study of the responses of roots of *Allium* and *Narcissus* to treatment with α-naphthaleneacetic acid, indolylacetic acid, indolylbutyric acid, β-naphthoxyacetic acid, α-naphthaleneacetamide and tryptophane, in concentrations varying from 0·001 to 0·002 per cent. Responses occurred first in the meristematic region, mainly in the cortex where cells underwent division in all planes. The development of numerous root primordia occurred in the roots of *Allium*.

3. Some Metabolic Effects of Growth Substances.

Mitchell and Martin (1937) applied 3 per cent. indolylacetic acid in lanolin to the first internode of etiolated bean seedlings (*Phaseolus vulgaris*). Galls and adventitious roots were developed at the point of application. Analysis of treated and untreated plants showed that materials were conducted from the cotyledons upward only as far as the point of treatment in the plants receiving indolylacetic acid, although there was no evidence of mechanical blocking.

Mitchell and Hamner (1938) decapitated seedlings of *Phaseolus vulgaris* growing in the light, above the second internode and applied lanolin containing various concentrations of indolylacetic acid to the cut surfaces. With concentrations above 0·00185 per cent. the development of axillary buds was retarded and the stem ends produced tumours and roots and the parts of the plants near the point of treatment increased more in fresh and dry weight than did similar parts of untreated plants. Lower concentrations retarded the buds less, no roots were formed, and the tumours were much smaller. Plants from which the axillary buds were removed were treated with dilute concentrations and showed final dry weights between 6 per cent. and 11 per cent. greater than control plants at the end of 6 days, although the leaf area present was not appreciably greater. The effect was most marked when the plants were grown in light of high intensity. Alexander (1938) obtained similar results and showed that carbohydrates were translocated towards the point of treatment. Czaja (1938) also demonstrated that treatment of plants with indolylacetic acid affected their nitrabolism and the rate of transfer of carbohydrates.

Stuart (1938) and Mitchell and Stuart (1939) worked with cuttings of *Phaseolus vulgaris* treated with 0·002 per cent. and 0·01 per cent. of indolylacetic acid solution for three hours. After treatment, the cuttings were set in sand and harvested at different periods up to 15 days, each sample being divided into roots, hypocotyls, first internodes, primary leaves, petioles and tips. Fresh weight, dry weight, total and insoluble nitrogen, reducing sugars and sucrose were determined for each sample. Treatment with the 0·01 per cent. of solution increased the dry weight of the hypocotyls and roots, and decreased the growth of the first internode and of the shoot tips. The dry weight of the primary leaves was not appreciably altered and the total weight of the whole cutting was not increased. During root formation nitrogen was transported to the first internodes and hypocotyls but subsequently disappeared. The sugar content of the cuttings was reduced.

Goldberg (1938) applied a 3 per cent. mixture of indolylacetic acid in lanolin to decapitated stems and to unwounded internodes of cabbage plants, grown at high and at low levels of nitrogen. All tissues of the stem responded to some extent to the treatment and especially the phloem, medullary rays and pith ; the cambium, cortex, endodermis and xylem showed a moderate, and the epidermis and pericycle a weak response. Adventitious roots were produced from pith cells adjacent to the primary xylem. The reactions were slower in the low nitrogen plants.

Doak (1941) treated *Forsythia* cuttings with α-naphthaleneacetic acid solution (1 in 30,000) for 24 hours and the lower inch of the cuttings was then analysed for reducing sugars, total sugars, amino-nitrogen, amide-nitrogen and ammonia nitrogen before planting, after 4 days, and thereafter at weekly intervals during propagation.

It was found that reducing sugars accumulated gradually in the treated cuttings but hardly at all in the control cuttings. Sucrose dropped sharply at first in both treated and control samples and later approached the original level in the controls only. Large increases in both amino-nitrogen and amide-nitrogen were found in treated samples but to a much lesser extent in the control ones. The general shape of the curves for reducing sugars and amide-nitrogen was, however, approximately the same in both control and treated cuttings and it was therefore concluded that a close relationship exists between reducing sugars and the amides. The treatment with α-naphthaleneacetic acid seemed to increase the rate and intensity of the normal change in metabolism taking place in rooting cuttings, rather than to cause any fundamental change. This speeding up process was reflected in the quicker appearance and greater number of roots in treated than in untreated cuttings. In a further paper Doak (1941) described experiments in which cuttings of *Rhododendron* sp. were treated with indolylbutyric acid (1 in 10,000), α-naphthaleneacetic acid (1 in 10,000) and α-naphthaleneacetic acid (1 in 10,000) plus alloxan 20 mg. per litre for 24 hours ; controls were treated with water for a similar period. The basal portions of the cuttings from each treatment series were analysed at intervals for sugars and for nitrogen fractions. It was found that α-naphthaleneacetic acid was more effective in mobilizing nitrogenous materials, with the exception of the non-protein nitrogen fraction, at the base of the cuttings than was indolylbutyric acid. On the other hand indolylbutyric acid exerted a greater effect on the sugars than α-naphthaleneacetic acid. The well defined difference in the action of indolylbutyric acid as compared with that of α-naphthaleneacetic acid, on the type of root and root system produced in cuttings, is therefore also reflected in differences in chemical reactions taking place in the tissues. The addition of alloxan to the α-naphthaleneacetic acid solution resulted in an increased rate of mobilization of sugars as compared with the acid alone. It was concluded that root formation only takes place when there is an adequate concentration of carbohydrate and nitrogenous material at the bases of the cuttings.

Overbeek, Gordon and Gregory (1946) showed that in *Hibiscus* cuttings the addition of an external supply of carbohydrate and nitrogenous materials aided rooting under the influence of indolylbutyric acid.

IV. PRACTICAL RECOMMENDATIONS FOR THE TREATMENT OF CUTTINGS

A. Substances to use.

Indolylbutyric acid is undoubtedly the most generally effective substance for the stimulation of root formation in cuttings ; it works well with a great number of species of plants and has a wide range of latitude without causing toxicity effects. Other useful substances are indolylacetic acid, α-naphthaleneacetic acid and α-naphthaleneacetamide, and with cuttings of a few species one or other of these substances is sometimes more effective than indolylbutyric acid. Mixtures of the substances can also be used.

B. Methods of application.

The three most useful practical methods of treating cuttings are (1) soaking in dilute solutions, (2) dipping in dust preparations and (3) dipping in concentrated solutions.

1. The Dilute Solution Method.

(a) *Preparation of the solution.*

A 1 per cent. stock solution can be prepared by dissolving 1 g. of the active substance or mixture in 50 ml. of 95 per cent. alcohol and then adding a further 50 ml. of tap water. Each millilitre of this solution then contains 10 mg. of hormone. The stock solutions keep well if stored in a cool dark place in dark coloured bottles until required. Indolylacetic acid is most liable to decomposition and α-naphthaleneacetic acid is the most stable. From this stock solution those of the requisite strength for treatment of the cuttings can easily be prepared by dilution.

One per cent. stock solutions of the pure substances can be purchased direct from a chemical supply house if desired, and there are also numerous proprietary solutions on the market, which are supplied with directions for use. These prepared solutions are very convenient in practice where accurate measuring apparatus is not available.

A selected list of plants which have been treated by various workers and the results obtained will be found in the table and this will serve as a guide for approximate concentrations to use.

The various measures of concentration that have been used by various workers are given below in equivalent terms.

Mg. per litre.	*Parts per million*	
2·5	2·5	1 part in 400,000
5·0	5·0	1 ,, ,, 200,000
10·0	10·0	1 ,, ,, 100,000
20·0	20·0	1 ,, ,, 50,000
40·0	40·0	1 ,, ,, 25,000
80·0	80·0	1 ,, ,, 12,500
100·0	100·0	1 ,, ,, 10,000
200·0	200·0	1 ,, ,, 5,000

(b) *Treatment of the cuttings.*

It is preferable to use freshly prepared cuttings, and to treat them as soon as possible with the solutions. If this is impossible the cuttings must be kept fresh until treatment, by covering with a moist cloth and spraying frequently with water. The treatment consists simply in immersing the bases of the cuttings to a depth of about one inch in the solution. A convenient time for immersion is 24 hours. During the immersion period it is advisable to shade from direct sunlight, otherwise water loss may be so rapid as to cause the cuttings to wilt, with fatal results. From the lower inch of the cuttings, which is immersed in the solution, the leaves should be removed as these tend to rot after planting, if submerged, thus causing the base of the cutting to decay.

The requisite concentration of solution for best results varies widely with different species, and to obtain the maximum rooting response the dose of hormone which the cuttings receive must fall within relatively narrow limits. It is therefore imperative to use the right concentration of solution for treatment. With excessive doses injuries will be caused such as the formation of masses of stunted roots, excessive swelling of the stem, or decay of stem tissue and rotting, which may result in early death of the cutting. An effective treatment is generally accompanied by some swelling of the stem upwards from the base of the cutting, and subsequent profuse root formation. It is probable with this soaking method that the effectiveness of the treatment depends largely upon the amount of hormone solution passing into the cutting. Any factor, therefore, which influences the rate of absorption of the solution such as temperature, humidity, light intensity, closeness with which the cuttings are packed during absorption, and the amount of leaf surface on the cuttings, will affect the response. As a rough guide the intending propagator can examine the list of treatments in the table which have proved effective, and then run a preliminary trial using ten or twenty cuttings as a unit with solutions at the effective concentration given, and also at double and half this strength.

After treatment the cuttings are rinsed and then set in the rooting medium.

(2) The Dust Method.

(a) *Preparation of the dust.*

The synthetic growth substance, if not already in a finely divided state, should be ground to a fine powder and then mixed thoroughly with the dust carrier by shaking well. Talc, mercurial dusts, or finely divided charcoal have all been found to be effective carriers. Alternatively the dust can be prepared by dissolving the hormone in 95 per cent. alcohol, and then stirring this solution into the carrier to make a smooth paste ; more alcohol can be added if necessary. The paste is then dried in the dark with a fan or in an oven at a temperature just sufficient to drive off the alcohol. During the drying period the mixture is stirred occasionally with a glass rod. A finely divided uniform powder should then be obtained. The dry dust can be stored in dark bottles in a cool place. Dusts containing from 2 mg. to 8 mg. of hormone to 1 gram of carrier are effective for many species.

Ready made dusts can also be purchased.

(b) *Treatment of the cuttings.*

The treatment consists simply in dipping the basal end of the cutting into the dust to the depth of about 1 inch, and then removing the excess powder by light shaking or tapping. The success of the method naturally depends to a large extent on the right amount of dust adhering to the cutting. The ends of the cutting can be moistened before treatment but excess moisture must be removed by shaking or wiping with a cloth, as if the cuttings are too wet an excessive amount of dust adhering to them may result in damage to the cutting. Sufficient dust for the job in hand should be placed in a separate container and any remaining should be discarded and not returned to the stock supply, as it may cause deterioration of the unused dust.

After the treatment the cuttings are planted directly, and care should be taken not to rub the dust off in inserting them into the rooting medium. It is therefore advisable to make a hole of requisite size in the medium with a knife or small stick, before inserting and firming the cutting.

(3) The Concentrated Solution Dip Method.

(a) *Preparation of concentrated solution.*

The solutions are prepared by dissolving the growth substance in 95 per cent. alcohol, and then diluting with water to give an approximately 50 per cent. alcoholic solution. Solutions containing from 0·5 to 1 gram of substance per 100 ml. alcohol (50 per cent.) are effective for many species, and even lower concentrations are sometimes preferred.

(b) *Treatment of the cuttings.*

The treatment consists of dipping the basal end of the cutting in this solution and then planting immediately. Immersion for one second is quite sufficient. Several cuttings can be dipped simultaneously.

As with the dust method used solution should not be returned to the stock supply: to avoid waste pour out only sufficient for daily needs.

C. Selection and care of cuttings.

It should be emphasized that after treatment the cuttings need the same careful handling as is normally given by the propagator. For example, where cuttings of a particular species are known to require special handling and special environmental conditions during the rooting period or the use of a particular rooting medium, these precautions should also be carried out in conjunction with the hormone treatment. With species, which are easy or only moderately difficult to root without treatment, optimal hormone treatment rarely fails to result in increased root formation, and the shortening of the time required for roots to form, thus ensuring a saving of time and allowing of the handling of many more cuttings during the season with the same propagating space. With species very difficult to root, however, a response is not always easy to obtain, and the use of hormones will not replace the careful attention to detail necessary without their use. The selection of the most suitable material, the age of the wood, the health and condition of the parent plant, the care of the cuttings while in the rooting medium, and the taking of precautions to minimize losses from disease, all remain essential considerations for successful results.

The treatment of cuttings after rooting should be the same as that normally given and if the treatment is optimal the subsequent growth of the treated cuttings should be at least as good as those rooted in the normal way.

D. Difficult species.

There are still many difficult species, and this is especially true where hardwood cuttings are used, which cannot be rooted with any certainty, even if growth substance treatments are applied. Stem cuttings of deciduous fruit trees which are not normally propagated by cuttings are a good example of this class. With these types no practical recommendations can yet be made, therefore, but recent work holds out the possibility that when all the factors influencing root formation in such material are known, methods which will make propagation of these difficult species and varieties by stem cuttings an economic proposition will eventually be worked out.

E. Testing the activity of the preparation used.

Probably many of the disappointing results obtained with hormone treatment are to be traced to the use of old or inactive preparations. If the activity of the preparation being used is in doubt, therefore, it is well worth while to test it before treating cuttings on a large scale. Hitchcock and Zimmerman (1938) found that single leaf cuttings of the tomato offer a simple and convenient test object. Two or three leaves from the middle portion of young tomato plants bearing from 8 to 9 leaves are severed at the base of the petiole. These leaves are then treated exactly like cuttings, and can be used to test dilution solutions, dusts or concentrated solutions by carrying out the usual procedure. After treatment the cuttings are set in sand or a mixture of sand and peat moss in a propagating frame. Cuttings treated with active preparations root in five to seven days, whereas, meanwhile, few roots emerge from control cuttings. Differences at this stage should be apparent to the eye, but if so desired the number of roots formed can be counted. Alternatively cuttings of some quick-rooting species such as privet can be used for a rough test.

THE TREATMENT OF SEED AND SEEDLINGS WITH GROWTH SUBSTANCES

I. SEED TREATMENT

A. Introduction.

Attempts to influence the subsequent growth of the plant by treating the seed with hormone preparations in dust and solution form have been very numerous. The results reported are, however, very conflicting, and the procedure cannot therefore be recommended for general horticultural practice. Positive results are, however, sufficiently numerous to lead one to the conclusion that there may at least be some stimulating effect under certain conditions. Whether these contradictory results are due to differences in environmental conditions under which the experiments have been carried out or to inherent variations in the different plant material used in the various tests, it is difficult to say. Precise conditions under which a response is likely to be obtained cannot therefore be defined and it seems that considerably more work needs to be carried out before the position can be satisfactorily clarified. Selected results which have been obtained by various workers are discussed and some of the factors which may have influenced the results are indicated where possible.

B. Soaking seed in growth substance solutions.

1. Early Work.

Cholodny (1936a) soaked oat seeds in a solution of β-indolylacetic acid (1-2 mg. per 100 ml. water) for 24 to 48 hours at 18 to 20° C. Seeds were also soaked in a solution of growth substance obtained from maize endosperm for a similar period. He claimed that the seeds treated with indolylacetic acid produced considerably stronger plants than untreated seeds, and that the yield in grain at harvest was 55 per cent. higher. There was, however, no difference in the date of flowering. The plants treated with the preparation from maize endosperm lagged behind the controls at first but later were far ahead and flowered twelve days earlier.

Chailakhjan and Zhdanova (1938) soaked seeds of various different species such as summer and winter wheat, oat, millet, vetch, hemp, white mustard, perilla, flax and peas for 24 hours in solutions containing 10, 25 and 50 mg. of indolylacetic acid per 100 ml. water. The effect of this treatment on the subsequent growth varied with the different species; the growth of oats was slightly accelerated, that of flax and vetch was checked, and that of mustard was decreased during the early growing period and accelerated later. In many cases, however, the plants reached the fruiting stage earlier.

Thimann (1936a and b) and Thimann and Lane (1938) found that after treatment of the seed of *Avena* and *Triticum* with relatively high concentrations of indolylacetic acid, the general vegetative growth of the shoot was accelerated, the leaves sometimes became longer and wider, and the dry weight of the plant was often increased by more than 50 per cent. There was also a slight hastening of flowering, presumably mainly due to the accelerated growth. The general growth acceleration was considered to be due chiefly to the action of the growth substance in causing the production of a larger root system.

Amlong and Naundorf (1937) soaked seeds of several different varieties for 24 hours in solutions of indolylacetic acid of concentrations ranging from 0·01 to 0·001 N. After this treatment the seeds not only germinated better but also developed into larger plants. Thus radishes showed an increase of 98 per cent. of root weight after treatment of the seeds with 0·001 N solution, and sugar-beet seeds soaked in 0·01 to 0·001 N. solution produced plants with larger leaves. In a later publication, the same authors (1938a) reported the results of further experiments and claimed that soaking sugar-beet seed, prior to sowing, in a solution of indolylacetic acid (0·01 N) resulted in a 157 per cent. increase in the weight of the crop, 129 per cent. leaf increase and 123 per cent. increase in sugar content. Treatment of seed potatoes, however, had practically no effect on the yield.

Davies, Atkins and Hudson (1937) soaked seeds of *Avena sativa*, *Lepidium sativum* and *Brassica alba* in solutions of various concentrations of indolylacetic acid. The germination and subsequent growth of the seedlings, which were germinated in Petri dishes, were retarded at all concentrations used.

Templeman (1939) also obtained negative results ; he treated seeds of white mustard for 24 hours before planting, in solutions of sodium β-indolylacetate at 50, 100, 200 and 500 mg. per litre, and sodium α-naphthaleneacetate at 5, 10, 20, and 50 mg. per litre. All the treatments with sodium β-indolylacetate produced plants with longer stems in the early stages of growth but there was no significant increase in the dry weight of the tops with any treatment after three months growth. Grace (1938a) also described experiments in which wheat seed was treated with a solution of α-naphthaleneacetic acid at concentrations from 0·01 to 100 p.p.m. In some cases there was a slight increase in the percentage of germination but the dry weight of the plants, after growing in soil, failed to show any appreciable increase from the hormone treatment.

2. Later Results with Various Seeds.

(a) *Positive results.*

Tang and Loo (1940) soaked seed of white mustard (*Sinapis alba*) for 24 hours in aqueous solutions of indolylacetic acid at concentrations of 1, 10 and 100 p.p.m. Leaf production during the pre-flowering period was stimulated in proportion to the concentration of hormone used ; high concentrations, however, reduced the number of leaves present at maturity. Mustard, tomatoes and rice grown from hormone treated seed bloomed from 3 to 7 days earlier than plants from untreated seed. Landau (1940) found indolylacetic acid to stimulate the germination of oats, French beans, tomato and radish seeds when used at concentrations of from 10^{-7} to 10^{-9}. Friedrich (1940) soaked seeds of potato, tomato and radish for 20 hours and potato tubers for 24 hours in hormone solutions and found root growth to be stimulated in comparison with top growth. The root/top ratio was thereby increased, although only occasionally was the total root system of the plants from treated seeds greater than that from the untreated seed. In a later paper Friedrich (1942) described experiments in which seeds of many different species were treated with hormones ; root growth was stimulated and a more stocky type of plant was obtained in several cases. Podeshva (1941) also claimed to have obtained increased and earlier crops of a number of vegetables by soaking the seed in indolylacetic acid solutions. Veldstra (1943) obtained an increase in percentage germination and bigger yields after treating the seeds and growing plants of tomatoes and cucumbers with indolylacetic acid. Swartley and Chadwick (1942) obtained increased germination and in some cases larger plants after two and a half months growth, by treating seeds of various perennials with hormone preparations, and Bouillenne and Walrand (1943) soaked seeds of maize in a 100 mg. per litre solution of indolylacetic acid before germinating and obtained increases of from 30 to 40 per cent. of ripe ears with four, different varieties when compared with plants grown from untreated seed. Zika (1943) also obtained slightly increased yields of barley by soaking seed in indolylacetic acid and also claimed that the malt showed an improved saccharification value.

(b) *Negative results.*

Barton (1940b) carried out comprehensive tests and reported the results of experiments in which many different kinds of quickly germinating seeds were treated with synthetic hormones in vapour, solution and dust form. In general, the results showed that neither the rate at which the seeds germinated nor the percentage of seeds germinating was influenced by the treatments. With tomato seeds the subsequent growth of the plants was not stimulated ; in fact in some cases considerable stunting was noticed ; with seeds of common garden flowers flowering was not influenced and with radishes the roots produced were often abnormal. Barton (1940a) also carried out hormone treatments with seeds which are normally difficult to germinate and which usually require special treatments, such as a period of low temperature storage, vernalization treatments or special environmental conditions, in order to obtain a satisfactory percentage germination. The main object was to discover whether hormone treatments could take the place of these special treatments. Treatment of apple seeds was ineffective. Seeds of *Ulmus americana*, however, which usually germinate well only after a period at low temperature, seemed to benefit slightly by the application of solutions of 35·5, 11·8 or 3·7 mg. per litre of potassium naphthaleneacetate. The influence was so slight, however, that it could not be used as a substitute for the usual treatments such as low temperature pre-treatment or soaking in water under light as a means of speeding up germination. The germination of seeds of *Cornus florida*, *Cornus stolonifera*, *Pyrus* sp. and *Pyrus malus* var. *niedzwetzkyana*, which had been after-ripened at 5° C., was inhibited by treatment with growth substances. This inhibiting effect was partially removed by a further treatment period at 5° C. but abnormal growth of the seedlings often resulted.

Lafferty (1940) soaked barley seeds in water solutions of indolylacetic acid (2 to 160 p.p.m.) and α-naphthaleneacetic acid (2 to 8 p.p.m.) and subsequently drained them for 5 minutes and then dried them in a current of hot air. The treatments had no beneficial effect on the germination of the seeds, growth of the plants, yield, malting quality or nitrogen content of the grain. The higher concentrations of α-naphthaleneacetic acid adversely affected germination and growth. Stewart and Hamner (1942) soaked seeds of various vegetable and field crop plants in a number of different hormone solutions using a wide range of concentrations. In both field and greenhouse trials no significant increase in growth was obtained. Koblet (1942) was also unable to recommend the treatment of seed with hormone solutions. Kiesselbach (1943) treated seeds of maize varieties and hybrids with aqueous solutions of indolylacetic acid, indolylbutyric acid, naphthaleneacetic acid and commercial hormone preparations. No significant benefits as regards germination, seedling development, time of maturity or yield were obtained from any treatment. Toxicity symptoms were noted in several cases. Lundegårdh (1943) also concluded that growth stimulation by hormone treatments was insignificant and of no practical use, and he could obtain no definite growth increases by the treatment of rye, oats, barley and sugar-beet seed with plant hormones.

3. Tests with Sugar-Beet Seed.

(a) *Positive results.*

Amlong and Naundorf (1941a) treated sugar-beet seed for 24 hours before sowing with solutions of potassium naphthaleneacetate at concentrations of 0·002 per cent., 0·010 per cent., 0·020 per cent. and 100 per cent. and then planted batches in different soil types, in different districts. The best concentration in every case was 0·010 per cent. and this treatment caused increased sugar content in the roots and increased yields. The authors stated that the seed must be soaked the full 24 hours and must be planted immediately after treatment. Some difficulty was apparently experienced in practice with the soaked seed tending to clog the drilling machine during planting. Zika (1941) also treated sugar-beet seeds with solutions of indolylacetic acid and α-naphthaleneacetic acid after first swelling the seeds in tap water. Increased yields of roots and leaves were obtained. Soaking the seed in water only, however, caused a considerable yield increase over that obtained with dry seed. Bouillenne and Roubaix (1942) obtained a 10 per cent. increase in the yield of sugar per hectare by just washing the seeds in running distilled water. A still further increase was obtained, however, by soaking the washed seeds in a solution of indolylacetic acid (0·5 gm. per litre), adenine, aneurine or nicotinic acid (0·004 to 0·008 gm. per litre). The effect was due to an increase in the size of the root ; the actual sugar content of the root was not influenced.

(b) *Negative results.*

Stehlik and Pazler (1941) obtained no benefit from treatment of sugar-beet seed with phenylacetic acid, indolylacetic acid, indolylbutyric acid or α-naphthaleneacetic acid as measured by size of root, sugar content, growth or yield. Dexter (1942) was also unable to find any benefit from the hormone treatment of sugar-beet seeds. Walrand (1942) treated sugar-beet seeds with solutions containing α-naphthaleneacetic acid, indolylacetic acid and thiourea before planting. The best yield was obtained from control samples which were soaked in water only. The quality of the beets from the hormone treated seed was inferior.

Decoux, Vanderwalren and Simion (1943) also failed to find any favourable effect of treating sugar beet seed with hormones ; in fact the germination of the treated seed was usually poorer and yield of sugar was reduced. Dykyj and Dykyj-Syfertora (1943) treated the seed of several varieties of sugar-beet with plant hormones. One kilogram of the seed of each variety was soaked for 24 hours in 3 litres of a solution containing 600 mg. of α-naphthaleneacetic acid. After the excess solution was poured off, the seeds were sown, either immediately or after 10 days storage. The germinating power of the seed was reduced in all cases, although the toxic effect was less pronounced if the seed was planted in moist cool soil, or after a period of dry storage. The treated beets developed a somewhat larger root system but the total yield per hectare was smaller from the treated seed. There was no definite effect on the chemical composition of the roots at harvest.

4. Tests with Potato Tubers.

Zika (1939) treated seed pieces of potatoes with indolylacetic acid and found that the subsequent yield of tubers was considerably increased and that the starch granules were considerably larger than usual. Varieties differed in their response to treatment. Walcher and Zika (1942) treated seed potatoes for 24 hours with a 0·00625 per cent. solution of indolylacetic acid and increased crop yields by 100 per cent. An increased percentage content of starch and an increased size of the starch granules was also a feature of the response. The effect was greatest when the seed was planted in rich dry soils of high nutrient content, and was much less when they were planted in poor wet soils. Alban (1945) also obtained yield increases of from 10 to 29 per cent. by treating potato seed pieces with indolylbutyric acid as compared with the yield from untreated seed pieces.

5. Increasing the Germination Percentage of Old Seed.

Amlong and Naundorf (1937) induced an increased percentage germination in old stored seed or seed reluctant to germinate by immersion for 24 hours in 0·01 or 0·001 N. indolylacetic acid solution. Grace (1938) conducted experiments with cereal grains and found that the reduction in germination and early growth resulting from formaldehyde treatment could be largely overcome by adding α-naphthaleneacetic acid or indolylacetic acid to the disinfecting solution. The optimum concentrations of the hormones for the treatment of individual varieties were between 0·01 and 5 p.p.m. Similar results were also obtained with hormone treatment after copper sulphate and hot water treatments.

C. The treatment of seeds with growth substances in dusts.

1. Some Positive Results.

Grace (1937) treated seeds with synthetic growth-promoting substances incorporated in talc or standard mercurial dusts, and at appropriate concentrations both root and shoot growth were markedly stimulated. For cereal seeds half an ounce of dust was applied per bushel of seed. Some optimum treatments, expressed as parts by weight of hormone per million parts by weight of seed were :—Wheat (a) 2 p.p.m. indolylacetic acid, (b) 2 p.p.m. indolylacetic acid +2 p.p.m. α-naphthaleneacetic acid, (c) 2 p.p.m. indolylbutyric acid. Treatment (a) gave 65 per cent. (b) 103 per cent. and (c) 55 per cent. increase in the length of roots as compared with untreated seed. The dry weight of the shoots were also increased up to 20 per cent. For barley and soya bean seed 2 p.p.m. and 10 p.p.m., respectively, of α-naphthaleneacetic acid gave optimum responses. McRostie, Hopkins and Grace (1938) applied concentrations of indolylacetic acid at 2·5 and 10 p.p.m., and 2 p.p.m. of a mixture of indolylacetic acid and α-naphthaleneacetic acid to 10 varieties of winter wheat, before planting in a replicated field trial. One half of each plot was planted with seed dusted with Ceresan (an organic mercury fungicidal dust), while the other half was sown with an equal quantity of seed of the same variety, dusted with Ceresan containing synthetic hormones. Ceresan was used throughout at the rate of ½ oz. per bushel, while the hormone concentrations given above are parts per million by weight of seed treated. The dusts were applied a few hours before planting, each lot of seed and dust being well shaken in a glass bottle to give a uniform distribution. The authors stated that some differences between the hormone-treated and the untreated sub-plots in respect of the early growth of the seedlings were apparent to the eye. Significant differences were also obtained in respect to straw production, and yield and weight per bushel of grain. Different varieties responded differently to the same treatment, and in general all treatments tended to reduce the nitrogen content of the grain. The maximum increase in grain yield for any variety was 13 per cent. and of straw roughly 20 per cent. The results varied greatly, however, with different varieties and the authors hesitated to draw any general conclusion without further investigation of dosages, varietal response and seasonal influences. Stier and du Buy (1938) treated tomato seeds with hormone-talc dust mixtures, and subsequently treated the young seedlings with solutions of either indolylbutyric acid or α-naphthaleneacetic acid, at the time of transplanting to the field. Certain combinations used in appropriate concentrations resulted in (a) marked acceleration of the time of anthesis of the flowers, (b) the production of a greater yield of fruit during the first month of the fruiting period, and (c) a greater total yield of marketable fruit for the entire season. The effective concentration of α-naphthaleneacetic acid in the dust mixture for seed treatment was considerably lower than that for indolylbutyric acid. Alpha-naphthaleneacetic acid in talc in concentrations of 10,000 p.p.m. and 100,000 p.p.m. caused marked inhibition in the rate of seed germination and delayed the flowering of the plants in the field. Greatest acceleration in flowering and fruit production, and the greatest total yield, was obtained by the treatment of 50 seeds with approximately 15 mg. of a dust mixture consisting of 10 mg. of α-naphthaleneacetic acid to 10 grams talc, followed by dipping the roots of the seedlings in an aqueous solution of indolylbutyric acid (10 p.p.m.) for about 2 seconds at the time of transplanting. Alpha-naphthaleneacetic acid, in similar concentration, for the dipping treatment at transplanting time, appeared to be detrimental to the flowering and fruiting of the plants in the field in almost all cases. One exception was in a treatment where indolylacetic acid was used in the dust medium as the initial seed treatment. Crosier, Stewart and Weimer (1940) obtained a slightly increased percentage germination of one variety of winter wheat by treatment with a dust containing indolylbutyric acid. Otherwise results with wheat and rye were negative. Hopkins (1940) studied the growth and yield of barley from seed dusted with 2·5 and 5 p.p.m. of indolylacetic acid in talc, with that from seed dusted with talc only. Germination was not affected, but when the seed was planted under conditions of sub-optimal water supply, treatment had the effect of increasing the height of the plants by about 3 per cent., and the dry weight of the straw by about 10 per cent., but did not cause an increase in the yield of grain. When the seed was planted under more favourable conditions and with optimal water supply, however, the hormone treatment had no appreciable effect.

Croxall and Ogilvie (1940a and b) treated seeds of lettuce, tomato, sugar-beet and dwarf beans with seed dressings containing talc, cuprous oxide, and zinc oxide. The talc used alone gave no significant effect on crop yield. In one experiment however, where cuprous oxide was used alone without any added hormone, lettuces were reduced in weight, but if synthetic growth substances were also added to the dust, no such diminution in yield occurred. They also obtained crop yields of peas up to 80 per cent. greater than those obtained from seeds treated with mercurial and copper seed dressings alone, by incorporating synthetic hormones in the dressings. Different varieties varied in their response, however, and external conditions had a considerable influence on the response obtained. Dressings containing 5 p.p.m. of α-naphthaleneacetic acid and mixed naphthylideneacetic acids were quite safe for the varieties used.

Amlong and Lauche (1943) working with tobacco obtained slight increases of leaf by disinfecting the seed with Germisan containing α-naphthaleneacetic acid or its potassium salt, or the potassium salt of indolylbutyric acid.

2. Negative Results.

Youden (1940) treated wheat and soybean seed in the dry state with talc dusts containing α-naphthaleneacetic acid, indolylacetic acid or with talc alone. No improved germination or increased growth was obtained and in fact untreated seed grew better than seed treated with talc alone or with talc containing the growth substances. Tests were carried out with seed planted in sand and in soil and under greenhouse and field conditions. Cornman and Bengstone

(1940) also could find no worthwhile benefit from treating seeds of Italian ryegrass and Kentucky bluegrass with talc dust mixtures of various hormones and commercial hormone preparations.

Gruenhagen (1940) treated seeds of Ontario pine and white pine with naphthalenepropionic acid (1 : 1,000 in talc) and indolylacetic acid (1 : 500 to 1 : 20,000 in talc). The percentage germination was not increased by this treatment and it did not protect the seed from the attacks of " damping off " fungi. Dexter (1943), too, found that no benefit was derived from treating seeds of numerous agricultural and horticultural crop plants with commercial hormone dust preparations, and Bartholemew (1944) also treated seeds of a number of crop plants including soya bean and grains with hormone dusts and obtained no significant increase in yield.

Stout and Tolman (1944) treated sugar-beet seed with dusts containing growth substances, before planting. Naphthaleneacetic acid, naphthaleneacetamide, indolylacetic acid, indolylbutyric acid, levulenic acid and commercial hormone preparations in concentrations ranging from 10 to 1,000 p.p.m. gave no significant benefits as regards germination percentage, vegetative growth, sucrose content or yield of roots per acre in both greenhouse and field experiments.

D. Other substances and methods used in seed treatments.

1. Vitamins.

Pollacci and Bergamaschi (1940) found Vitamin C to accelerate germination and growth of the orchids *Cattleya labiata autumnalis* and *Oncidium pulvinatum* and Zopf (1940) considered that the vitamins B and C used as an addition to α-naphthaleneacetic acid, in dust treatments of the seed of *Atropa belladonna* and *Ricinus communis*, somewhat neutralized the toxic effects produced by overdoses of the hormone.

Algren (1941 and 1942) found that concentrations of thiamine of 0·01, 0·1, 0·8 and 1·6 mg. per litre added to seeds of several grass species and clover failed to increase the percentage germination.

2. Animal Hormones.

Marinchik (1939) soaked seeds of sugar-beet for 24 hours in various concentrations of ovarin and insulin and found the treatments to increase root yield. The sugar and protein nitrogen content of the roots was also said to be increased. Ovarin reduced the non-protein nitrogen content while insulin increased it.

3. Some Organic Acids.

Blagoveshchensky and Kologrivova (1945) found that the growth of roots of *Phaseolus aureus* was stimulated by soaking the seed in solutions of succinic acid (M/2,000) and aspartic acid (M/6,000).

Decoux and Vanderwalren (1944) obtained increases in yield of sugar up to 5·8 per cent. by soaking sugar-beet seed in a solution containing 2 mg. per litre of nicotinic acid.

4. Thiourea.

Soaking seed in solutions of thiourea has sometimes increased the percentage germination. Thus Thompson and Kosar (1939) and Thompson and Horn (1944) showed that the percentage germination of lettuce seed could be increased by soaking it in a 0·5 per cent. solution of thiourea.

Tukey and Carlson (1945) also found that the germination of peach seed was encouraged by thiourea treatment. A 0·25 per cent. solution was usually the best concentration ; higher concentrations sometimes caused injuries to the embryos.

Thompson (1946) using the seed of endive (*Cichorium endivia*) found that soaking in a 0·5 per cent. solution of thiourea for 8 hours at 18° C. gave the highest germination percentage. Soaking in tap water alone, however, resulted in considerably better germination than with untreated seeds and was in fact almost as effective as thiourea at the optimum dosage. Eighteen different strains of endive were tested altogether and it was found that the strains which germinated poorly without treatment showed the greatest response to the thiourea treatment.

5. Saponin.

Balansard and Pelissier (1945) found that soaking tomato seeds for 24 hours in a very dilute solution of saponin accelerated germination and growth of the seedlings.

6. Sulphanilamide.

Ribiero (1944) tested the influence of sulphanilamide on the germination of rice seeds. A solution of 1 in 10,000 was found to retard embryo development while a solution of 1 in 2,000 had a still greater effect without killing the embryo.

7. Manganese Sulphate.

Loo and Tang (1945) soaked seed of several species in a solution of manganese sulphate for 24 hours using a wide range of concentrations and found the rate of germination to be accelerated and the growth of the seedlings to be improved. They considered this treatment to be superior to a treatment with either indolylacetic acid or colchicine, both of which substances produced toxic after-effects following germination.

8. Urine Extracts.

Molotkovskii and Porutskii (1939) soaked seed of wheat, millet and barley in an oil extract of pregnant mares' urine, and also smeared potato tubers with a paste containing the urine concentrate. It was found that the growth development of the plants was promoted. Porutskii (1941) concentrated urine obtained from a pregnant mare to one-tenth volume, extracted it with fish oil and diluted the oil extract to the original volume with water. 0·5 ml. portions of this were then injected into the eyes of potato tubers, or alternatively 1 ml. portions were injected 2 to 3 cm. from the eyes, and the treated tubers were then planted in experimental plots. Tubers similarly treated with urine free oils were planted at the same time to serve as controls. It was claimed that germination and flowering were earlier and that the yield and the starch content of the crop was increased by the urine injections. Pastes consisting of 2 ml. of urine concentrate and 8 gm. of petroleum jelly were also prepared from the urine of pregnant mares and pregnant women. These pastes were applied three times, at two day intervals, to the eyes of potato tubers and the tubers were then planted. The plants from the treated tubers were of stronger growth and more forward than those from similar, untreated tubers. It was subsequently found that similar effects could be obtained by using urine from non-pregnant women or mares.

9. Yeast Extracts.

Söding and Funke (1943) obtained a slight increase in yield of roots by soaking carrot seed in yeast extract ; onions did not respond similarly. The extract used was prepared by boiling yeast in tap water for 20 minutes, making up to the original volume and filtering.

10. Effect of X-Ray Treatment of Seed.

Smith and Kersten (1942) considered that the effects of the X-ray treatment of seeds could be best explained by the influence of the rays on the production and distribution of the natural hormones in the seedlings grown from the treated seed.

E. Germination Inhibitors.

One aspect which must always be kept in mind in assessing the results of seed treatment is the effect of the treatment on natural substances present in the seed or seed coat. Thus it is well known that germination inhibiting substances are often present in the seed and seed coats of many plants and can sometimes be removed by a simple washing in water. The literature of this subject cannot be fully reviewed here but an exhaustive bibliography can be found in a paper by Evenari (1940). Isip (1939) showed that the seed of numerous plants contain inhibiting substances which in most cases can, however, be easily removed by soaking or washing the seeds with water before sowing. Tolman and Stout (1940) also found that water soluble substances present in the seed balls of sugar-beets produce a toxic effect on the germination of the seed. These substances could be readily removed by washing the seed balls for six hours in running water. Soaking the seed in a large volume of water to ensure dilution of the toxic substances was definitely beneficial but not so effective as washing the seed in running water. The amount of these germination inhibiting substances present varied with the variety and also with different lots of seed of the same variety.

Ozorio de Almeida, Goulart, Gelpo and Pinto (1941) found that a substance present in tomato juice inhibited the germination of tomato, lettuce, sunflower, cabbage and endive seeds. The actual substance causing this effect was soluble in alcohol but not in ether or chloroform. Dilute juice allowed germination, but the seedlings were deformed. Seeds treated with undiluted juice and then washed in water did not germinate. Ullman (1940) showed that essential oils and alkaloids are capable of inhibiting the germination of seeds of many different species, although sensitivity varies considerably.

THE TREATMENT OF GROWING PLANTS

I. THE EFFECT ON HORTICULTURAL AND CROP PLANTS

A. Some characteristic responses.

Hitchcock and Zimmerman (1935) showed that synthetic plant hormones applied as solutions to the soil of plants growing in pots were absorbed by the roots, and responses such as epinasty of the leaves, and the formation of roots on the stems of the plants occurred. The dry weights of the plants were not determined after such treatment, but from visual observation it was apparent that the growth of the tops was retarded. Pearse (1937) sprayed young tomato plants with a 0·1 per cent. solution of either phenylacetic acid or indolylbutyric acid. A daily application was given and resulted in increased height of the plants, and longer petioles and internodes. The balance between various parts of the plants was altered considerably, after one and two weeks treatment : phenylacetic acid treatment depressed root and leaf growth but increased the growth of stem and petiole ; while indolylbutyric acid treatment depressed leaf growth, but increased that of root, stem and petiole. The total dry weight of the plants, however, was never higher than that of untreated control plants. In a later communication Pearse (1937) described the effects of applying indolylacetic acid to broad bean plants (*Vicia faba*) growing in water culture ; 1 ml. of a 0·1 per cent. aqueous solution was applied daily, either in the nutrient solution to the root or to the tops of the plants by spraying. The growth in length of the roots was greatly retarded by the former treatment, but they were thicker and more numerous, so that the total dry weight of the root system was not altered : spraying the tops decreased the weight of the root system without altering its form. The total dry weight of the plants was decreased by both treatments.

Marmer (1937) grew wheat seedlings in solutions containing indolylacetic acid indolylpropionic acid or indolylbutyric acid employing a wide range of concentrations and with the acidity of the solutions adjusted at pH 4·6 and 7·5. At both acidity levels the growth of the primary root, coleoptile and first leaf was decreased but the number of secondary roots formed was increased. More lateral roots were formed in the acid than in the alkaline solutions. Macht and Grumbein (1937) studied the action of extremely dilute concentrations of indolylacetic, indolylbutyric and α-naphthaleneacetic acids on the root growth of *Lupinus albus* seedlings and found that the growth of the roots was definitely stimulated, after a brief exposure to a very weak solution of any of the three substances used. Longer exposures to the same concentration and exposures for the same period to a higher concentration, however, invariably produced a toxic or inhibitory effect. A typical example was as follows : an exposure of 15 minutes to a solution of indolylacetic acid at a concentration of 1 in 1,000,000 resulted in an increase in root growth, whilst an exposure of 30 minutes to the same concentration caused a decrease.

Grace (1937) reported that the growth of young seedlings of tomato, nasturtium and salvia, watered daily with 50 ml. of a nutrient solution containing synthetic growth substances, was greatly increased. The optimal concentrations of either indolylacetic or α-naphthaleneacetic acid lay between 1/10 and 1/100 p.p.m. With decreasing concentrations the effect diminished and increasing concentrations led to injury and death. The reaction was most marked in sand cultures, less so in soil, and the extent of the stimulation was greatest in very young plants.

Amlong and Naundorf (1937) reported that spraying plants with indolylacetic acid at a concentration of M/100 accelerated vegetative growth and flowering. Loehwing and Baugness (1936) and Greenfield (1937) reported that the addition of a dilute solution (1 in 15,000) of indolylacetic acid to the soil produced a slight acceleration in the growth of young seedlings. This acceleration was not maintained, however, and disappeared after ten days. McEvoy (1939) considered that the rate of growth of both tops and roots of tobacco seedlings was accelerated by the application of appropriate concentrations of indolylacetic acid. In a later publication McEvoy (1942) stated that the application of a 2·5 p.p.m. solution of indolylacetic acid at the rate of 250 ml. of a 2·5 p.p.m. solution per square foot was adequate for tobacco seedlings, the first application was made just subsequent to planting out the seedlings and was found to be definitely beneficial in stimulating the growth of the plants.

Laude (1941) supplied indolylacetic acid at a concentration of 10^{-9} to the nutrient solution used for growing plants of *Phaseolus vulgaris* in sand cultures. Increases as great as 12·5 per cent. in total dry weights were obtained. With naphthaleneacetamide at a concentration of 10^{-6} dry weight of roots was increased 35 to 40 per cent. but the growth of the tops was reduced.

Gross (1940) germinated seeds of the mungo bean (*Phaseolus radiatus*) in distilled water, and when the primary roots were about 1 cm. long the seedlings were placed in beakers, between the sides of the vessels and an internal cylinder of filter paper. Different beakers were then filled with either water or solutions of indolylacetic acid at concentrations of 0·001, 0·01, 0·1, 1·0 or 10 p.p.m. After 3 days there was a slight stimulation of root growth at 0·001 p.p.m., visible stunting at 1 p.p.m. and total inhibition of the main root with stimulation of secondary roots at 10 p.p.m. Hypocotyl growth was depressed 35·2 per cent. at 10 p.p.m. as compared with the water control. After 7 days, however, hypocotyl growth exceeded that of the controls in all cases, with the optimum at a concentration of 0·01 p.p.m. Epicotyl growth with all concentrations was less than in the controls after 4 days, but exceeded that of the controls after 6 days. It was concluded that the epicotyl is more sensitive to growth substances than the hypocotyl.

Moinat (1943) observed that indolylacetic acid sprayed on the leaves of lettuce plants in summer resulted in the production of more open heads, lighter green leaf colour and shorter and thicker stems. Zimmerman (1943) showed that the form of plant organs could be extensively modified by the application of growth substances. Substituted phenoxy, benzoic and naphthoxy acids were particularly active in this way. Fully mature parts were not reactive but new growth occurring after treatment was greatly affected. Leaves were changed in shape and in some cases showed patches of light and dark tissue and translucent veins. It was pointed out that many of the effects produced very strongly resembled the symptoms induced by plant viruses. The response varied with the type of plant and the chemical used. Synerholm and Zimmerman (1947) in studying the effect of a homologous series of ten 2,4-dichlorophenoxy aliphatic acids and their amides showed that only members of the series possessing an even number of carbon atoms in the aliphatic acid portion of their molecules were active in modifying growth. The amides were also much more likely to cause toxic effects than the free acids.

Ross (1939) found that certain *Epilobium* hybrids exhibited abnormal growth such as shortened internodes and curled leaves. These abnormalities could be corrected by daily spraying with dilute solutions of indolylacetic acid. It was therefore thought that the abnormal growth in these seedlings was the result of the oxidative inactivation of the natural growth hormones.

B. Total growth not increased.

Templeman (1939) carried out pot-culture experiments in which solutions of indolylacetic acid, α-naphthaleneacetic acid, skatole and ascorbic acid were applied to plants by spraying on to the foliage and by watering on to the sand. No significant increases in dry matter production were obtained. Mitchell (1939) sprayed bean plants with aqueous solutions of indolylacetic acid containing 300 mg. per litre and found that their growth was repressed: weaker solutions had little effect. Solutions containing 10 to 300 mg. per litre had no appreciable effect on the total growth of marigold plants although marked bending and curling of the leaves occurred after repeated treatments. Solutions of indolylacetic seed in oil or in water were also sprayed onto oat and bean plants growing in the open, but their growth was not appreciably affected. The fresh weights of the tops of bean plants growing in the field which were irrigated with solutions of indolylacetic acid containing 0·01 and 1·0 p.p.m. were, however, slightly greater than those of untreated plants. A similar response could not, however, be obtained with marigold plants.

Hamner (1940) found that adding α-naphthaleneacetamide to the nutrient solution used for growing red kidney bean plants resulted in less top growth, but increased root growth.

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The percentage content of calcium, phosphorus and nitrogen was also increased, and the xylem and phloem were more extensive and matured earlier than that of untreated plants. Spraying the plants with hormone solutions did not produce similar effects. In a later paper, Hamner (1942) could find no particular benefit from adding small quantities of phenylacetic acid or naphthaleneacetamide to the soil of tomato plants grown in pots. Even the most dilute concentrations 10^{-10}, resulted in reduced growth.

Swartz (1941) applied α-naphthaleneacetic acid, contained in a complete nutrient solution, at a concentration of 0·1 mg. per litre and failed to stimulate the growth of chrysanthemum, marigold or cosmos seedlings, and Raleigh (1942) applied solutions of α-naphthaleneacetic acid at 15 p.p.m. and at 5 p.p.m. to growing carrots. This treatment resulted in considerable root deformity. Zimmerman (1947) considers that there is at present no established proof that any of the synthetic growth substances stimulate the growth of the whole plant.

II. THE EFFECT ON VARIOUS OTHER PLANTS

A. Water plants.

Clark and Frahm (1940a and b) added indolylacetic acid, phenylacetic acid and phenylpropionic acid to cultures of *Lemna major* growing in inorganic nutrient solutions, under controlled light and temperature, the solutions being renewed twice weekly. The growth substances applied at concentrations of 0·01 mg. per litre or lower failed to increase the rate of reproduction. Intermediate concentrations up to 10 mg. per litre retarded frond production, and concentrations above 10 mg. per litre killed the plants. Intermittent treatment did sometimes increase the rate of reproduction, however, without causing injury to the plants.

Funke (1941 and 1942) found that petiole growth of water lilies (*Nymphaea*) was stimulated by hormone solutions. An effective concentration was 0·25 mg. per litre of α-naphthaleneacetic acid.

B. Mosses.

Fries (1943) found that the growth of the protonema of *Funaria hygrometrica* L. was greatly stimulated by dilute solutions of indolylacetic acid (0·01 γ per c.c.).

C. Liverworts.

Witsch (1940) added very dilute solutions of indolylacetic acid to cultures of liverworts growing on nutrient agar. At appropriate dosages, germination and development was stimulated, but there was no increase in the final size of the frond or in cell size.

D. Algae and fungi.

Leonian and Lilly (1937) attempted to stimulate the growth of fungi and algae by using various concentrations of indolylacetic acid ranging from 1 part in 10,000 to 1 part in 10,000,000 of nutrient medium. Without exception it was found that the higher concentrations proved toxic and the lower concentrations failed to induce any stimulation.

Pratt (1938b) grew *Chlorella vulgaris* for three weeks in nutrient solutions to which were added various concentrations of synthetic growth substances. Cell multiplication was markedly increased in the presence of 50 p.p.m. indolylacetic acid, indolylpropionic acid or indolylbutyric acid. Concentrations of 10 p.p.m. also caused appreciable stimulation, indolylacetic acid being the most and indolylbutyric acid the least effective. Similar increases could not be brought about by the addition of glucose to the nutrient medium. Lilly and Leonian (1941) however, failed to obtain any growth increase, as measured by dry weight, as the result of the addition of indolylacetic acid or phenylacetic acid to cultures of *Chlorella vulgaris*.

III. THE USE OF GROWTH SUBSTANCES IN TRANSPLANTING

A. Treating the roots with solutions.

Chadwick (1937c) soaked the roots of three-year-old plant of *Viburnum dilatatum* and *Cotoneaster divaricata* for 18 hours in aqueous solutions containing 20, 50 and 100 mg. per litre of indolylacetic acid, indolylbutyric acid or phenylacetic acid. *Viburnum* responded well to indolylbutyric acid at 20 mg. per litre, new root formation being increased sevenfold ; *Cotoneaster* responded best to 50 mg. per litre. A good response was also obtained by adding 10 or 20 mg. of growth substance to the soil in 5 inch pots.

Tilford (1938) experimented with seedlings of American elm, hard maple, black oak, pin oak, black walnut, white pine, Norway spruce and American arbor vitae. The seedlings were dug up in January and the roots soaked for 48 hours in a solution of indolylbutyric acid of 25 mg. per litre concentration. The seedlings were then potted and kept in a greenhouse until April. Most species showed considerable stimulation as regards new root growth, but white pine and Norway spruce seedlings did not respond well.

In other tests American elm and red oak saplings were root pruned, and the root system remaining was soaked in indolylbutyric acid for 48 hours at a concentration of 40 mg. per litre. The saplings were then planted in the open; by the end of the season the number of roots present had been doubled as the result of the treatment.

Plank (1939) soaked the roots of slash pine seedlings in aqueous solutions of indolylbutyric acid, at concentrations between 10 and 80 mg. per litre for 24 hours, and claimed some stimulation in root development when the lower concentrations were used.

Swartley (1941) also found that treating the roots at transplanting time with growth substance preparations stimulated root and stem development in woody plants, such as crab-apples, honeysuckle and juniper, in perennial bedding plants such as *Coreopsis* and in annuals such as tomato and the aster. The watering of grafted stocks of red cedar with solutions of plant hormones resulted in increased survival and the more rapid development of absorbing roots. Amlong and Naundorf (1941b) immersed the roots of *Vicia faba* seedlings for from 3 to 24 hours in 0·001 M solutions of potassium α-naphthaleneacetate or potassium indolylacetate and then grew them on in sawdust. After 10 days a considerable increase in the number of lateral roots was observed. It was also found that immersing the roots of young plants in growth substance solutions before planting in the field resulted in increased yields. Successful results were obtained with tobacco seedlings and with six *Brassica* species. With pansies the number of blooms produced was said to be increased by 65 per cent. in some cases.

Maki and Marshall (1945) soaked the roots of eastern red oak and loblolly pine seedlings for 24 hours in aqueous solutions of indolylbutyric acid in concentrations ranging from 2·5 to 160 mg. per litre. With red oak root growth was significantly increased during the first growing season when a treatment with a solution containing 40 mg. per litre was used. Treatment with concentrations of 80 mg. per litre or more caused more of the seedlings to die, although those that survived showed increased root growth. With loblolly pine seedlings root growth was also increased somewhat, but heavy mortality occurred when solutions stronger than 20 mg. per litre were used.

Beneficial results have not, however, always been obtained, for example Sayre (1939) using concentrations of 50 mg. of α-naphthaleneacetic acid or 250 mg. of indolylacetic acid in 50 gallons of water, applied one pint of either solution to young tomato plants at transplanting time. These applications were not effective in increasing yields and moreover tended to delay maturity. Fowells (1943) soaked the roots of *Ponderosa* pine seedlings in indolylacetic acid at 5, 25 or 50 mg. per litre and then planted them either in nutrient solutions or in soil. Slightly longer roots were obtained in nutrient solution with the 5 mg. per litre treatment, and more secondary roots in soil as the result of the 50 mg. per litre treatment. No special advantage in practice, however, could be found as the result of treating the seedlings after 1 month storage at 41° F., and Fowells concluded that treatment of coniferous seedlings with growth substances before planting was of doubtful practical value. The same conclusion was also reached by Zach, Bauer and Goodyear (1943).

Sparks (1945) also failed to find any advantage in applying hormone solutions to onion seedlings at transplanting time, and Doak and Greenwood (1947) stated that in tests carried out in New Zealand no worthwhile practical stimulation had been obtained with a variety of plants.

B. Treatment with dusts.

Swartley and Chadwick (1942) treated rooted cuttings of *Lonicera fragrantissima*, with hormones in talc dust, before planting in shaded beds or in pots in a cold frame. The substances used were Transplantone No. 1 (a commercial hormone preparation), nicotinic acid 1 in 1,000 and thiourea 1 in 20,000. Top growth was improved when the plants were placed in the shade provided by a lath house, but not in plants placed in a cold frame. Nicotinic acid gave an especially good response. Dusting the roots of seedlings of *Malus sieboldii arborescens* with indolylbutyric acid dust (1 in 5,000) and with Transplantone caused the production of clusters of new roots. Seedlings of *Juniperus virginiana* also responded by producing new roots when watered with Transplantone, but no response was obtained with *Picea* seedlings.

C. The toothpick method.

Romberg and Smith (1939) had observed that nursery grown pecan trees usually make very little growth for the first two years after transplanting, and found this to be due largely to the slowness with which a vigorous root stem was re-established. Root-forming substances were therefore tested for hastening the development of new roots. Encouraging results were first obtained with root cuttings after applying indolylbutyric acid in lanolin, either smeared on the bases of the cuttings, or applied in slits or holes made through the bark ; the second method was superior. Tests were therefore subsequently carried out using comparable groups of 5- to 7-year-old pecan nursery seedling trees. The method of treatment was as follows. The pointed ends of ordinary round toothpicks were cut off, leaving the middle portion which was then cut to a length of 4 cms. Solutions of indolylbutyric acid were prepared in 95 per cent. alcohol, and the prepared toothpicks were then soaked in these solutions for 24 hours. They were then removed and air dried. In the preparation of toothpicks carrying 4 mg. of the acid, 1 gram of indolylbutyric acid was dissolved in 21 ml. of alcohol. Each toothpick absorbed approximately 0·084 ml. of the solution. In applying the treatments, holes were bored transversely through the roots with an electric drill and the prepared toothpicks inserted. Toothpicks carrying 0·5, 1, 2 and 4 mg. per toothpick were tried ; those carrying 4 mg. of the acid proved most effective, and the treatment greatly increased the production of new roots. Gossard (1942) also treated young pecan trees by this method, and inserted four toothpicks each carrying 4 mg. of indolylbutyric acid in the root system of each tree. The treated trees showed significant increases of root growth but not of shoot growth. Smith (1947) experimented with seedling pecan trees of 4 to 6 years old, and bored small holes at four different places in the taproot of each tree, and inserted in each hole a half toothpick carrying approximately 2 mg. of indolylbutyric acid, giving a total treatment of 8 mg. per tree. As the result of this treatment, the young trees made more new root and new shoot growth than similar untreated ones. Smith also followed the chemical changes in the treated and untreated trees and determined the percentages of sugars, starch, hemicellulose, organic nitrogen and dry matter of the taproot wood, the taproot bark and the trunks at transplanting and at intervals during the first growing season. The decrease in starch content was 1·6 times greater in treated trees than in untreated trees. In general, changes in composition showed the same general trend in treated and untreated trees, and the relatively greater intensity of the changes in the treated trees was a reflection of the greater metabolic activity and greater production of new root and shoot growth.

D. Foliage treatments.

Ostrum (1945) examined the possibility of using growth regulating substances to prevent extensive top growth of coniferous seedlings in the nursery. Emulsions containing 50 g. of lanolin and 5 g. of soap per litre together with the synthetic growth substance were applied as sprays. These sprays, which contained from 200 to 600 mg. of naphthaleneacetamide, 200 mg. of naphthaleneacetic acid or a mixture of growth substances were not very promising, as weaker concentrations did not result in sufficient inhibition of shoot growth and higher concentrations resulted in deformed growth and excessive mortality. It was thought that the treatments might be more successful with deciduous trees.

Treatments were also applied just before transplanting to the tops of seedlings of red, shortleaf and loblolly pines, and to roots, tops and whole plants of red spruce and tulip tree, using concentrations of α-naphthaleneacetic acid and other hormones from 80 to 1,000 mg. per litre. These treatments had no particular advantage, however, and usually caused considerable numbers of the seedlings to die. Tulip tree seedlings showed a slightly increased root growth. For conifers the application of a plain lanolin emulsion or commercial wax (30 to 50 mg. per litre) immediately before planting resulted in a higher survival when planting took place in the spring months, but not at other times of the year.

IV. THE TREATMENT OF GROWING PLANTS WITH OTHER SUBSTANCES

A. Vitamins.

1. Some Positive Results.

Bonner and Greene (1938) added vitamin B_1 at the rate of 1·0, 0·1 and 0·01 mg. per litre to the nutrient solution used for sand cultures of various species of plants growing in a glasshouse. The addition of the vitamin was found to increase the shoot growth of species of plants which are normally slow growing, but had no effect on the growth of fast growing annual plants. They pointed out that organic manure contains appreciable amounts of vitamin B_1 and the beneficial effects of manure upon plant development may possibly, therefore, be partly due to its vitamin B_1 content. Bonner and Greene (1939) in a later paper considered that the numerous species of plants that did not respond to vitamin B_1 additions contained more vitamin B_1 in the leaves than plants which did respond. They therefore suggested that the vitamin B_1 content of the leaf could be used as an indication of whether or not a given species would be likely to respond to vitamin B_1 treatment by increased growth.

Bonner and Bonner (1940) found that vitamin B_6 increased the growth as measured by dry weight, particularly of the roots of mustard, cotton and cosmos plants. Adenine at concentrations below 1 γ per litre of nutrient solution added to sand cultures increased the dry weight of seedlings of *Cosmos sulphureus* threefold. The effects of adenine and vitamin B_1 were not additive however, possibly, it was thought, because treatment with adenine stimulates the natural production of vitamin B_1 by the plant. Wheat and tomato plants did not respond to additions of vitamins B_1 or B_6, œstrone or adenine.

Murneek (1940) found that vitamin B_1 applied at concentrations of from 0·025 to 50 mg. per gallon of water had beneficial effects on the growth of *Cosmos*, dill and ornamental pepper plants, whether the plants were growing in poor or in rich soil. Equally good or better results were obtained, however, by the simple expedient of placing a half or three-quarter inch layer of leaf mould on the surface of the soil. Fraps and Fudge (1942) increased the size of zinnia blooms slightly by applying a solution of vitamin B_1 to the plants, and the growth of pansy plants was also stimulated somewhat by the same treatment. The growth of many other species tested could not be stimulated by a similar treatment. André (1939) treated sugar beet seedling plants with aqueous solutions of vitamin B_1 (0·66 mg. per litre and 0·132 mg. per litre) and could notice no noticeable change during the first leaf stage. Vitamin B_1 (0·2 mg. per litre), however, caused an increase in size and sugar content during the two leaf stage and during the six leaf stage. Vitamin B_6 (0·5 mg. per litre) caused the production of larger plants but with a lower sugar content.

Tuge (1941) found that the addition of ascorbic acid slightly improved the growth of seedlings of *Phaseolus radiatus* but had no effect on the protein, fat, carbohydrate or ash content of the plants. Dennison (1940) applied ascorbic acid in nutrient solutions to tobacco seedlings at the rate of 10 p.p.m. Considerable growth stimulation was obtained with young plants, but the effect decreased with older plants.

Noggle and Wynd (1943) found that orchid seeds could be grown in artificial medium when a technical grade of maltose was used. In an attempt to discover the impurity responsible for this effect thiamine, ascorbic acid, calcium pantothenate, riboflavin, pyridoxine and nicotinic acid were tested. Nicotinic acid addition to the cultures containing purified maltose resulted in good germination and development.

Dennison (1940) added 2·5 p.p.m. of synthetic riboflavin to a nutrient solution used for watering pot cultures of eggplant (*Solanum melongena*) growing in gravel. Growth was greatly increased.

2. No Response to Vitamin B_1.

Although growth stimulation has occasionally been obtained under special circumstances and with a few species of plants as the result of treatment with vitamin B_1 there is no evidence that the procedure has any general application in horticultural practice. Haber and Edgecombe (1940) applied weak solutions of vitamin B_1 to a number of different plants but failed to find any marked stimulating action, and Hamner (1940) supplied vitamin B_1 with the nutrient solution to plants of several different species growing in sand cultures. The treatment had no effect on growth even when applied to plants growing at low or high levels of nitrogen or under long or short photoperiods. Evers and Laurie (1940) could find no benefit from adding vitamin B_1 to nutrient solutions used for the gravel culture of orchids, and Arnon (1940) also found that tomato, cosmos, lettuce, mustard and cockleburr plants grown in nutrient solutions did not respond to vitamin B_1 additions. Templeman and Pollard (1941) obtained no response, using tomato and spring oats as test plants, and Myers, Jugenheimer and Heyne (1941) treated hybrid maize and Kaffir corn plants with vitamin B_1 solutions and also found no stimulating effect. Algren (1941 and 1942) added vitamin B_1 as an amendment to fertilizer mixtures, for grasses and clover, and failed to obtain any growth stimulation, although determinations showed that the vitamin had been absorbed by the plants and was indeed present in higher concentrations than in untreated plants. Bensend (1942), however, treated jack-pine seedlings growing in sand irrigated with nutrient solutions with thiamine and niacin. After 80 days analysis of the tissues showed that untreated plants contained as much thiamine as the treated ones and no differences in size or weight of the seedlings resulted. Tincker (1942) also failed to find any benefit from supplying vitamin B_1 to tomato plants and Tukey (1942) considered that there was nothing to recommend the use of vitamin B_1 in plant culture, and thought that most of the growth increases attributed to its use were due to extra care given to the treated plants.

Minnum (1941a and b) added vitamins B_1, B_2 and B_6 to nutrient solutions supplied to radish and cauliflower plants and found no appreciable growth promoting effect and Minarik (1942) found no response with rice plants to vitamin B_1. Clark (1942) added vitamin B_1 solutions to plants of *Brassica alba* and *Agrostis tenuis* growing both in soil and in sand cultures ; no influence on the growth of plants was discovered. Gesiger (1944) added thiamine to various species of plants growing in pots. These included sunflower, wheat, flax and bean plants. No increase in growth or yield was obtained over those of untreated plants, and it was concluded that although the vitamin may be indispensable for growth, apparently these plants are able to elaborate sufficient themselves internally for their normal development.

Donelly (1941) watered the soil in which nine species of woody plants were growing with vitamin B_1 solution (0·05 mg. per litre). Growth was not stimulated and in some cases the treatment had an adverse effect. The plants treated included the following species ; *Chilopsis*, *Fraxinus velutina*, *Gleditsia triacanthos*, *Juglans hindsii*, *Olea verrucosa*, *Prosopsis juliflora*, *Simmondsia californica*, and *Acacia farnesiana*. Parker, Turrel and Bonner (1941a and b) applied solutions of vitamin B_1 and nicotinic acid to newly planted Valencia orange trees on sweet orange stocks. Growth was not stimulated above that of untreated trees.

3. Response of Lower Plants to Vitamins.

Although the vitamins in general appear to have no appreciable stimulating effect on the growth of higher plants given as an external application, it is well established that they are essential for the growth of many of the fungi and algae when these are grown in purified cultures. The higher plants with their highly specialized cellular organization are evidently capable of producing these substances in sufficient quantities for their own needs, whereas many of the fungi and algae with their relatively simple cellular structure evidently rely on their hosts or their substrate for their supply.

B. Fluorescent dyes.

Sellei (1941) and Sellei, Sellei, Mayer and Went (1942) claimed that fluorescein acts as an inhibitor or as a stimulator of plant growth depending on the concentration applied. Working with plants of tomato and marigold they used either fluorescein dissolved in a solution of sodium carbonate or a commercial preparation known as " Photosensin " which is composed of 93·9 per cent. sodium carbonate, 5 per cent. fluorescein, 1 per cent. iron sulphate and 0·1 per cent. copper sulphate. These were applied in various concentrations to plants growing in sand cultures and growth was stimulated or depressed according to the concentration used. Zuck (1944) has criticized these results and considered that the number of plants used in the experiment was too small for the data obtained to have high accuracy. Zuck carried out experiments with larger numbers of kidney bean plants (*Phaseolus vulgaris* L.) grown in pure quartz sand with nutrient solutions to which were added in different series "Photosensin" and its constituents, namely fluorescein, iron sulphate, sodium carbonate, and copper sulphate. Visible difference amongst the various series were small and so were differences in dry weight. Dry weight was slightly increased in the series receiving the copper sulphate. No evidence could be found, however, for any growth promoting effect by fluorescein and the stunting effect of high concentration of fluorescein was considered to be due to the toxic effect of the amounts of sodium carbonate necessary to keep the fluorescein in solution.

V. THE RELATIONSHIP BETWEEN GROWTH SUBSTANCES AND NUTRITION

A. Zinc, copper and manganese.

Skoog (1940) studied the relationships between auxin and zinc using tomato and sunflower plants grown in highly purified solution cultures in a greenhouse. Comparative experiments with copper and manganese deficient plants were also included. It was found that decrease in auxin content preceded the appearance of zinc deficiency symptoms, while a large increase in the auxin content of zinc deficient plants occurred from one to a few days after applying zinc and a few days later growth was resumed. In contrast manganese and copper deficient plants did not show a reduced auxin content until the deficiency symptoms had appeared. Zinc deficient plants also inactivated indolylacetic acid more rapidly than control plants did, and had a higher oxidation capacity. Adding indolylacetic acid to the culture solution or spraying it on the leaves of zinc deficient plants increased stem growth during the early stages of deficiency, but could not replace zinc as a nutrient. It was concluded that zinc is not principally active in the synthesis of auxin but is required to maintain it in an active form. Lack of zinc was thought to lead to excessive destruction of auxin probably by oxidation and this leads to retardation of growth and malformed growth.

B. Boron.

Eaton (1940) considered that indolylacetic acid could to some extent replace boron as an element essential to the growth of root, stem, leaf vein and other leaf blade tissues. This conclusion was reached as the result of experiments carried out with cotton plants, and Eaton suggested that possibly boron is essential for the formation of auxin in plants. Moinat (1943), however, applied indolylacetic acid to boron deficient lettuce plants by spraying and concluded that indolylacetic acid did not prevent the appearance of boron deficiency symptoms.

C. Potassium.

Laude (1941) investigated the effects of growth substances applied to sand cultures of the red kidney bean (*Phaseolus vulgaris*) receiving different levels of potassium nutrition. Indolylacetic acid appeared unable to replace potassium or to enhance its utilization under deficiency conditions. With high potassium nutrition, however, increases as great as 12·5 per cent. in total dry weight of plants were obtained by supplying indolylacetic acid at a concentration of 10^{-9}. Swartz (1941) studied the effect of applying growth substances to chrysanthemum plants growing in complete nutrient solutions and in solutions deficient in magnesium, potassium and phosphorus. Alpha-naphthaleneacetic acid was supplied at the rate of 0·1 mg. per litre of nutrient solution and it was considered that α-naphthaleneacetic acid may in some degree compensate for lack of potassium, but not for that of magnesium or phosphorus.

D. Hormones in soils and manures.

Attempts have been made to correlate the effect of organic manures and different soil types with their hormone contents. Parker Rhodes (1940) worked out a method of detecting and measuring small amounts of indolylacetic acid in soils and showed that mixing farmyard manure with soil tended to increase the quantity of the acid present. Hamence (1945) concluded that most of the common organic manures contain indolylacetic acid. Poultry manure (2 weeks old) was a particularly rich source, the total auxin content expressed as indolylacetic acid amounting to 7·66 mg. per 100 g. on a dry weight basis.

E. Effect of growth substances on carbon nutrition.

Cholodny and Gorbovsky (1939a, b and c), using leaves of lilac, poplar, jasmine, hemp, hydrangea and other plants, stated that the introduction of very low concentrations (1 : 1,000) indolylacetic acid into the leaf caused a temporary increase in photosynthetic activity (100 to 200 per cent.). Immersion of leaves for several hours in a (1 : 100) solution of indolylacetic acid solution did not, however, have the same effect.

THE USE OF GROWTH SUBSTANCES IN PRODUCING PARTHENOCARPIC DEVELOPMENT OF FRUIT

I. INTRODUCTION

It has been known for a very long time that in a few cases amongst flowering plants, e.g. species of *Thalictrum*, *Alchemilla* and some other plants that the egg cell may develop into an embryo, although unfertilized. Parthenocarpic fruit development is, also, of course, a commonplace in certain varieties of fruit of the seedless type, i.e. bananas, grapes, oranges and persimmons. Many varieties of pears also occasionally produce seedless fruit when pollination has failed or the opportunity for cross pollination is lacking, although in many cases such fruits are somewhat deformed and not of the characteristic shape of the normal pollinated fruit. Attempts to produce parthenocarpic fruits experimentally started many years ago and several workers, Massart (1902), Hartley (1902), Fitting (1909 and 1910), Winge (1917) and Yasuda (1933, 1934a and b, 1936) were more or less successful in producing parthenocarpic fruit development in various species of plants by the use of pollen of unrelated species, by the use of sterile pollen and finally by the use of pollen extracts. The inducement of parthenocarpic development in commercial fruits by the application of the plant growth substance and synthetic chemicals is, however, a comparatively recent development, but nevertheless promises to become a practice of considerable economic importance in horticulture.

II. EARLY WORK WITH GROWTH SUBSTANCES

Gustafson (1936) induced the parthenocarpic development of fruits of tomato, pepper, crook-neck squash, egg plant, *Petunia* and *Salpiglossis* by applying 1 per cent. lanolin pastes of indolylacetic acid and other synthetic hormones to the stigma or cut surface of the style. He failed, however, to secure such fruits in watermelon, summer and winter squash and pumpkin, and results with cucumber were also not consistent. Hagemann (1937) obtained parthenocarpic fruits of gladiolus by similar treatments. Gardner and Marth (1937a and b) produced parthenocarpic fruits of American holly (*Ilex opaca*) by spraying the pistillate flowers with α-naphthaleneacetic acid, indolylbutyric acid or indolylpropionic acid in different concentrations. A few parthenocarpic fruits were also obtained on strawberry plants using indolylacetic acid, but self-sterile varieties of apple and grape gave negative results. Hubert and Maton (1939a and b) obtained small parthenocarpic fruits of pumpkins and normal sized ones of gladiolus by treating the ovary with a 2 per cent. lanolin paste of α-naphthaleneacetic acid. By powdering the stigma with pure crystals of the same substance, parthenocarpic fruits of a *Cymbidium* hybrid and of *Oncidium longipes* were obtained. Parthenocarpic fruits of two *Crinum* species were also obtained by the paste method and also by injection of the ovaries with a solution of α-naphthaleneacetic acid at a concentration of 250 mg. per litre, and a number of fully ripe parthenocarpic fruits of *Fuchsia* were successfully produced. Wong (1939) found that indolylacetic acid and indolylbutyric acid of 0·5 and 1·0 per cent. strength, applied as lanolin pastes to the ovary, did not induce parthenocarpic fruit in a commercial variety of orange, even though natural parthenocarpy existed in this type, and Varrelman (1938) sprayed a normally parthenocarpic type of apple (*Malus apetala*) with different concentrations of indolylacetic and α-naphthaleneacetic acids and failed to set fruit. Wong (1939) was successful in obtaining parthenocarpic fruits of cucumber, watermelon and pepper using lanolin pastes of α-naphthaleneacetic acid.

Schroeder (1938), using tomato plants, found that when a lanolin paste of indolylacetic acid (1 in 500) was applied over the entire ovary, the percentage of flowers set compared favourably with normal and hand pollination treatments. The average weight of the fruit from the hormone treated flowers was not, however, so great as that of normal fruits. Applications of the paste to the stigma or to the end of the cut off style were not nearly so effective.

III. THE USE OF GROWTH SUBSTANCES IN TOMATO PRODUCTION

A. Practical aims.

Arising from the early work on the production of parthenocarpic fruits by the application of synthetic growth substances many investigators have studied this problem, with the object of developing methods which will be of practical use in commercial horticulture. The tomato has probably received more attention in this direction than any other fruit, and the object of this work has been not only the production of seedless fruits, but also the equally, if not more, important aim of using growth substance treatments as a supplement to normal pollination. It is well known that where attempts are made to grow tomatoes during the season of the year when days are short and light intensity low, normal pollination often fails, owing to the prevalence of sterile pollen. There is every reason to hope that suitable growth substance treatments, applied under such conditions, will help considerably to obtain a satisfactory crop.

B. Methods.

1. Lanolin Pastes.

Most of the earliest work on parthenocarpy induced by growth substances was carried out by the application of lanolin pastes, but the method is obviously too tedious for large scale application. Howlett (1939) treated emasculated flowers of the Globe and Marhio varieties of tomato with 0·5 per cent. pastes of indolylbutyric acid and indolylacetic acid. The size of the fruits produced by the aid of indolylbutyric acid exceeded the size of those from self-pollinated flowers and they were also considerably larger than fruits obtained from flowers treated with indolylacetic acid. Indolylacetic acid treatment seemed especially promising in that injury to the flower was practically nil; the fruits produced were of good quality, well formed and well developed and the ovules showed some development but were much smaller than seeds. Strong (1941) was also successful in inducing parthenocarpic development in the John Bear tomato by applying 0·5 per cent. pastes of indolylbutyric acid. Application to the cut surface of the style was more effective than application to the intact stigma. Development of the fruit was also accelerated and the time taken from set to harvest was reduced by as much as 5 days.

Hilton (1944), too, found α-naphthaleneacetic acid and indolylbutyric acid, applied as lanolin pastes in concentrations ranging from 0·01 to 5·0 per cent., to be quite effective for producing parthenocarpic tomato fruits.

2. Spraying.

Zimmerman and Hitchcock (1941) sprayed the flowers and flower buds of tomatoes with a solution of β-naphthoxyacetic acid and found this substance very effective for producing parthenocarpic fruits. The ovaries enlarged even before the flowers opened and another interesting response was that the floral parts persisted for an abnormally long time during the subsequent development of the fruit. Howlett (1941 a and b) found that, under greenhouse conditions, the set of tomatoes from pollinated flowers was usually considerably increased by spraying the ovaries with 0·3 per cent. indolylbutyric acid in a lanolin emulsion containing stearic acid and triethanoline. The treatment increased the size of the first cluster fruits by as much as 50 per cent. Under some conditions, however, the development of blossom end rot appeared to be favoured by the use of this spray, whereas the application of lanolin pastes did not have this adverse effect. Indolylacetic acid, α-naphthaleneacetic acid, methyl indolylbutyrate, α-naphthaleneacetamide, α-naphthalenethioacetamide and potassium naphthaleneacetate were also tried, but were not so effective as indolylbutyric acid.

Swarbrick (1942) sprayed flowers of the Plumpton King variety of tomato with dilute solutions of β-naphthoxyacetic acid and with α-naphthaleneacetic acid, using a hand-operated atomizer. From the point of view of inducing the development of parthenocarpic fruits the results were disappointing and, moreover, the plants received a severe check to their development, especially those sprayed with naphthoxyacetic acid. Marked epinasty of the parts sprayed occurred within 12 to 14 hours after application and within 10 days the general growth of the plants began to fall behind that of unsprayed control plants. In a later paper Swarbrick (1944b), however, found that both β-naphthoxyacetic acid at 30 p.p.m. and 2,4-dichlorophenoxyacetic acid as weak as 1 p.p.m. were effective in inducing the development of parthenocarpic fruits from emasculated tomato flowers. Beta-naphthoxyacetic acid was used at concentrations as strong as 50 p.p.m. without causing serious malformation of the plants ; 2,4-dichlorophenoxyacetic acid was, however, very apt to cause damage and deformed growth, if used in slightly too high a dosage. Fruits produced with β-naphthoxyacetic acid were practically normal in flavour and texture, whereas those produced with 2,4-dichlorophenoxyacetic acid were insipid, rather sweet and mild in flavour, with a loose mealy flesh texture. They were also often elongated in shape, beaked and partially hollow.

Zimmerman (1943) suggested the following concentrations of active substance as the most effective for use in aqueous solutions as sprays for tomatoes ; β-naphthoxyacetic acid 100 mg. per litre, *p*-chlorophenoxyacetic acid 50 to 100 mg. per litre and dichlorophenoxyacetic acid at 10 mg. per litre.

Roberts and Struckmeyer (1944) found that thoroughly wetting tomato blossoms with water solutions of β-naphthoxyacetic acid (75 mg. per litre) or 2,4-dichlorophenoxypropionic acid (7·5 mg. per litre) proved a practical method of setting the lower clusters on early and late winter crops of greenhouse tomatoes. Sprayed fruits were inclined to show greenness around the placental areas, but otherwise did not differ from normal pollinated fruits. Howlett (1945) also found the application of β-naphthoxyacetic acid or indolylbutyric acid in aqueous solution to be effective in accelerating ripening and increasing the early production of tomatoes, provided water supply to the plants was adequate for good growth.

Swarbrick (1945a) obtained a 100 per cent. set of tomato flowers by spraying with a dried ether extract of tomato flowers gathered just prior to anthesis and taken up in alcohol ; in spraying ester salts were added as a wetting agent. 4-4′-dihydroxydiethyl stilbene at 50 and 100 p.p.m. and hexoestrol were other substances effective in causing parthenocarpic development of tomato fruits.

3. The Aerosol Method.

This method, which was first used for the application of insecticides, consists in releasing a mixture or solution of the active chemical and a liquified gas through a suitable nozzle, from a small cylinder or " bomb " container. Hamner, Schomer and Goodhue (1944) dispersed 240 mg. of β-naphthoxyacetic acid per 1,000 cubic feet of greenhouse space. They dissolved 3 g. of β-naphthoxyacetic acid in 27 g. of cyclohexone and placed the solution in a small steel cylinder into which 270 g. of dimethyl ether were then forced under pressure. This mixture when released in the glasshouse was quite effective in causing parthenocarpy and fruit set of tomato flowers. Hamner, Schomer and Marth (1944) tested the effectiveness of several substances by the aerosol method for inducing set of tomatoes. It was found that 4-chlorophenoxyacetic acid is very effective in setting fruit and in stimulating early fruit growth ; the best concentrations to use was 0·01 per cent. as it was found that higher concentrations resulted in the development of abnormal leaves and fruits. Beta-naphthoxyacetic acid was also very effective for use by the aerosol method. The safest and still effective range of concentration for this chemical was between 0·01 and 0·5 per cent. Not all the fruits from treated flowers were seedless and some pollination might have occurred ; early fruit growth was greatly stimulated. Very good results were also obtained by using a mixture of 4-chlorophenoxyacetic acid at 0·1 per cent. and β-naphthoxyacetic acid at 0·25 per cent. Indolylacetic acid, indolylbutyric acid and α-naphthaleneacetic acid were much less effective.

Zimmerman and Hitchcock (1944a and b) used three different kinds of cylinder for dispersing aerosol growth substance mixtures. One consisted of a small cylinder with a spring attachment for stopping the flow and was very useful for making local applications to flower clusters. A second was a cylinder holding two pounds of mixture and was used for dispersing aerosol mixtures throughout an entire greenhouse. The mist or fog produced by using this cylinder persisted in a closed house for from two to five hours. A third cylinder manufactured by the Bridgeport Brass Company of Bridgeport, Connecticut, U.S.A., held one pound of Freon growth substance mixture and was equipped with an easily opened and closed needle valve. This was said to be very useful for treating plants in the open. In all cases the growth substances were dissolved in acetone, sesame oil and a liquified gas, dichlorodifluoromethane (Freon) being added. As active chemical ethyl α-(2-chlorophenoxy)-propionate, using from 100 to 450 mg. to 2,500 cubic feet of greenhouse space, gave a very good set of fruit.

Howlett and Marth (1946) carried out extensive tests with the aerosol method using (1) indolylbutyric acid 0·025 per cent., (2) β-naphthoxyacetic acid 0·025 per cent., (3) indolylbutyric acid 0·0125 per cent. and β-naphthoxyacetic acid 0·0125 per cent. and (4) indolylbutyric acid 0·0125 per cent., β-naphthoxyacetic acid 0·0125 per cent. and 4-chlorophenoxyacetic acid 0·001 per cent. The growth regulating substances were placed in the cylinders in 5 per cent. cyclohexanone and 94·975 per cent. dimethyl ether. The aerosol application was applied to each flower cluster as it developed, taking care not to hit the stem, and from one to three applications were made to each cluster and in addition the clusters were shaken to aid natural pollination. The aerosol method which has the advantage of being quicker for application to clusters, was compared with the ordinary spray method in which water solutions and emulsions are used. Yield increases of from 20 to 40 ounces of fruit per plant were obtained by all three methods, which meant in practice increases of from 11,250 to 22,250 lbs. of fruit per acre.

The most satisfactory aerosol treatment in this work was found to be the use of a mixture of the three chemicals, β-naphthoxyacetic acid, indolylbutyric acid and 4-chlorophenoxyacetic acid combined ; β-naphthoxyacetic acid used alone gave quite good results, however, and repeated (three) applications of aerosol to each cluster were more satisfactory than a single application.

The aerosol method did not always compare favourably with the more usual spray method however, for example, in a test in one greenhouse, although yields were very satisfactory, the aerosol treatment resulted in the production of fruits that were oversized, frequently hollow and with poor pulp production, whereas fruits resulting from an emulsion spray treatment were practically normal. In another greenhouse, on the contrary, the aerosol treatment gave practically as good results as the best aqueous emulsion spray applications. The reasons for this variation are somewhat obscure, but it was thought that variations in environmental conditions in the two greenhouses may have been responsible. However, more trials appeared to be necessary before the aerosol method, although quicker, could be recommended for general application by growers.

4. The Vapour Method.

Zimmerman and Hitchcock (1941) introduced the vapour method of applying growth substances in which the active substance is vaporized on a hot plate in a closed greenhouse.

Strong (1944) made a special study of the effectiveness of the vapour method for inducing parthenocarpic fruit development and set in tomatoes, and found the method to be distinctly promising, provided the greenhouse was relatively air tight. The vapour was produced by warming weighed amounts of the ethyl ester of β-naphthoxyacetic acid on an electric hot plate, and an electric fan, placed about six feet from the hot plate, was used to disperse the vapour. The hot plate was allowed to run for about 30 minutes and the fan for about 2 hours. A dosage of 10 mg. of β-naphthoxyacetic acid per 1,000 cubic feet of greenhouse space, for 15 hours, appeared to be an optimum dosage for this chemical. Two treatments applied at a 5-day interval during the blooming period of any one cluster were more effective than a single treatment, and vapours were more effective upon freshly opened flowers than upon buds or old flowers. During periods of short day length, β-naphthoxyacetic acid applied as a vapour failed to stimulate complete filling of all the locules in 10 to 15 per cent. of the fruits produced. It was stressed that for success with the vapour method, the glasshouse must be relatively air tight, as any considerable deviation from the optimum dosage resulted in injury, if too high, or poor results, if too low.

5. Soil Application.

Zimmerman (1942b) stated that seedless tomato fruits had also been produced by adding some of the substituted phenoxy compounds to the soil in which the plants were growing, but that the method had not reached the stage at which it could be recommended for practice.

C. Field Application.

Zimmerman and Hitchcock (1944a and b) obtained encouraging results using the aerosol method of application on plants growing in the field. One mixture used was made with 20 ml. of acetone, 10 ml. of sesame oil, 500 mg. of the ethyl ester of *a*-(*o*-chlorophenoxy)-propionic acid and 1 lb. of Freon. By this method one hundred per cent. set was obtained on the first clusters of young Marylobe tomato plants growing in the open. Thus they considered that, although still in the experimental stage, the aerosol method showed distinct possibility for field use.

Luckwill (1946a) also considered that sprays of β-naphthoxyacetic acid might prove beneficial for field cultivated tomatoes, and stated that preliminary trials had held out the possibility of a 100 per cent. or more increase in crop, in some cases. He pointed out, however, that as growing conditions could not be subjected to the same measure of control in the field as in a glasshouse, the results obtained might vary considerably according to the seasonal climatic conditions and the varieties grown.

D. Some practical considerations.

1. Substance to Use.

In the early work with tomatoes (Howlett 1941) indolylbutyric acid was extensively used for inducing fruit set and parthenocarpic fruit development, but one of the disadvantages of this chemical was the relatively high concentration necessary.

Zimmerman and Hitchcock (1944a and b) list a large number of chemicals which are effective in stimulating fruit set and development in tomatoes, but some are only effective in high concentrations, while others are very liable to inhibit the growth of the plant and damage the leaves. They considered that four of the most promising chemicals were 2-chlorophenoxy-propionic acid, 2,4-dichlorophenoxyacetic acid, 2,5-dichlorobenzoic acid and β-naphthoxyacetic acid.

For practical use, however, β-naphthoxyacetic acid appears to be the most promising substance. It has the advantage of being less likely to cause serious growth inhibition and malformation of the plants, and the fruits produced are normal in shape and of a good quality. For spray application Luckwill (1946a) recommended a concentration of from 40 to 60 p.p.m. for use under English conditions. Doak and Greenwood (1947) state that β-naphthoxyacetic acid has been found satisfactory for use with tomatoes in New Zealand.

2. How and When to Make the Application.

Luckwill (1946a) stresses the following important points in making spray applications. The practical grower will probably find it most convenient to use one of the commercial preparations which are now on the market. These are usually sold in concentrated form and contain a wetting agent. For use, the preparation is diluted with water to the required strength according to the instructions supplied by the manufacturers. The spray can be applied with a small hand sprayer or with a knapsack sprayer, and the flower trusses should be sprayed when the flowers are open, and in such a manner that good penetration of the liquid around the inside of the flower and ovary is obtained. The spray should be kept off the foliage as much as possible and especial care should be taken not to wet the growing point of the plant or subsequent growth will be affected. It is recommended that flower clusters should be sprayed when the last flowers are opening, as at this time a single application will usually result in the setting of all the fruits present. With exceptionally large trusses, when the period of flower opening is of considerable length, two sprays with an interval of 10 to 14 days, depending on the rate at which the flowers are opening, can be applied.

3. Importance of Cultivation Methods.

The use of the fruit-setting sprays do not in any way allow any relaxation in the normal careful attention to details of cultivation such as correct watering, and correct nutrition of the growing plants. The treatment does, however, hold out the possibility of enabling the grower to obtain a satisfactory crop of good quality fruit when days are short and light conditions poor, and when normal pollination fails owing to the prevalence of sterile pollen.

IV. RESULTS WITH OTHER PLANTS

A. Strawberry.

Wong (1941), using sprays of 50 and 500 p.p.m. of α-naphthaleneacetic acid, obtained parthenocarpic fruits of strawberries, on potted plants growing in a greenhouse. Hunter (1941) obtained parthenocarpic fruits of three pistillate varieties of strawberry (Louise, Portia and Simcoe) on plants growing in a greenhouse, by spraying unpollinated blooms with solutions of indolylbutyric acid, α-naphthalene acetic acid and colchicine, and by dusting the flowers with powdered acenaphthene. There was also some development of fruit from blossoms which were not directly treated and this was attributed to the translocation of the chemical or some other substance from the treated, to the untreated blooms. It was suggested that the action of the chemical might be indirect and due to the mobilization of some other substance or substances into the ovary.

Swarbrick (1942) sprayed Tardive de Leopold strawberry plants in full bloom with α-naphthaleneacetic acid and with β-naphthoxyacetic acid. The α-naphthaleneacetic acid caused considerable twisting and distortion of the petioles and had no apparent effect on fruit set, and, moreover, delayed the ripening of pollinated fruits for over 21 days. The naphthoxyacetic acid spray, however, greatly improved the set and many unpollinated flowers developed into perfectly shaped fruits with very little seed development. This spray also had the advantage of causing much less malformation of the plant than α-naphthaleneacetic acid. The increase in yield due to the use of the naphthoxyacetic acid spray was estimated to be at least one ton per acre.

Swarbrick (1944b) also applied an aqueous solution of β-naphthoxyacetic acid (20 p.p.m.) as a drenching spray from a knapsack sprayer to Tardive de Leopold strawberry plants in full flower, growing in alternate strips with Royal Sovereign strawberry plants. The blossoming of the Sovereign plants was nearly over at the time of application. An increase in yield of 940 lbs. per acre in favour of the treated plants was obtained and this was statistically significant. The increase in weight of the crop was due largely to an increase in the size of the individual fruits.

B. Blackberry.

Marth and Meader (1944) sprayed blackberry blossoms at the stage when 50 per cent. of the flowers were open and 5 per cent. remained unopen and the remainder had already formed small green fruitlets, with solutions of indolylacetic acid, indolylbutyric acid, β-naphthoxyacetic acid, and 4-chlorophenoxyacetic acid. Aerosol applications were also made. All treatments resulted in an increase in the weight of the berries and the earlier time of application of the spray gave the best results. For example, an increase in berry weight of 99 per cent. resulted from treatment with an aqueous spray, at a concentration of 40 p.p.m., of a mixture consisting of 40 per cent. of 4-chlorophenoxyacetic acid and 60 per cent. of β-naphthoxyacetic acid. This treatment stimulated the development of the receptacle and the pulp of individual drupelets and increased the number of drupelets per fruit. Waldo and Hansen (1946) carried out similar experiments using 2,4-dichlorophenoxyacetic acid at 20, 40 and 80 p.p.m. and a mixture of 4-chlorophenoxyacetic acid 40 p.p.m. and ortho-chlorophenoxypropionic acid 40 p.p.m. Carbowax was used as a carrier in preparing the solutions. The size of the drupelets was definitely increased by 2,4-dichlorophenoxyacetic acid treatment, although some injury to the flowers resulted. Ortho-chlorophenoxypropionic acid was not so effective. Different varieties of blackberry showed different degrees of response.

C. Beans.

Murneek, Wittwer and Hemphill (1944a and b) sprayed snap beans with aqueous solutions of α-naphthaleneacetamide and β-naphthoxyacetic acid, using a range of concentrations from 5 to 25 p.p.m. The sprays were applied every other day, beginning when the first flower buds appeared and ending shortly before the last harvesting of the pods. Increased crops were obtained when the crop matured under unfavourable high temperatures, but crops grown in spring and autumn under cooler conditions did not benefit and might in fact be harmed by the sprays. Dilute sprays (5 p.p.m.) applied every other day appeared to give the best results. The results were, however, too variable for any recommendations to be made for practical usage.

Wittwer and Murneek (1946) obtained fairly consistent results with snap beans by applying a solution of *p*-chlorophenoxyacetic acid at 2 p.p.m. as a wetting spray. Dusts were also tried but were not effective. Using this compound, yield increases of 10 to 25 per cent. were obtained when weather conditions for flowering and pod development were normal. When the pods matured under hot dry unfavourable conditions, the treatment gave much bigger yield increases over untreated control plants. The pods also matured more quickly on the treated plants. Wittwer, Murneek (1946) and Hardenburg (1944) could not recommend similar treatments for peas, lima beans or dry shell beans. In these cases it is seed yield and not pod yield which is desired, and the main effect of the growth substance treatment is the stimulation of the development of the pod tissues.

D. Some other plants of minor practical importance.

1. Melons, Watermelons and *Cucurbita* spp.

Burrell and Whitaker (1939) considered that indolylacetic acid could be used to advantage in melon breeding to reduce the abscission of pollinated flowers.

Wong (1941) was successful in producing parthenocarpic fruits of a number of *Cucurbita* species by applying α-naphthaleneacetic acid in lanolin pastes or by spraying. In some cases a mixture of α-naphthaleneacetic acid and acenaphthene gave better results than the use of either substance alone.

Wong (1941) also obtained moderate success in producing parthenocarpic seedless watermelons (*Citrullus vulgaris*) by treating the cut style with a mixture of acenaphthene and α-naphthaleneacetic acid.

2. Eggplant and Peppers.

Howlett (1939) obtained small but satisfactory fruits of eggplant (*Solanum melongena*) and pepper (*Capsicum annuum*) by treating the emasculated flowers with lanolin pastes containing 2 per cent. of indolylacetic acid, although a smaller percentage of the flowers developed into fruits than occurred with normal self-pollinated flowers. Wong (1941) was also successful in producing parthenocarpic fruits of eggplant and of pepper. With the eggplant, the largest fruits were produced by using a paste containing a mixture of one per cent. α-naphthaleneacetic acid and 10 per cent. acenaphthene ; 1 per cent. indolylbutyric acid or 1 per cent. α-naphthaleneacetic acid used alone were successful, but the fruits were much smaller.

3. *Lantana sellowiana.*

Pomeroy and Aldrich (1943) found that spraying the flowers of *Lantana sellowiana* with solutions of α-naphthaleneacetic acid, indolylacetic acid or indolylbutyric acid was effective in inducing fruit development, provided the flowers were sprayed after removal of the corollas.

4. Petunia.

Gustafson (1936) and Hilton (1944) found that parthenocarpic fruits could easily be induced in petunia by the application of lanolin pastes or sprays of indolylacetic acid, indolylbutyric acid or α-naphthaleneacetic acid.

5. Potato.

Hilton (1944) stated that lanolin pastes or sprays of α-naphthaleneacetic acid or indolylbutyric acid were ineffective, in attempting to produce parthenocarpic potato fruits.

6. Apples and Pears.

Early attempts to induce the development of parthenocarpic fruits or improve fruit set in apples and pears by the application of growth substances were almost invariably unsuccessful. Gardner and Marth (1937), Burkholder and McCown (1940).

Varrelman (1940) and Greene (1943) all reported failures in attempting to increase fruit set of various varieties of apples by applying growth substances to the blossoms. Greene (1943) tried lanolin pastes, sprays and branch injections without success and wax emulsions containing α-naphthaleneacetic acid, applied about a month after full bloom, retarded the development of the young fruits.

Van Stuivenberg (1941) made many attempts using paste and spray preparations, but no great success was obtained. With the pear Précoce de Trévoux, however, spraying the intact flowers or treating the cut styles with lanolin paste preparations gave a slightly higher percentage of parthenocarpic fruits.

Podeshva (1942), however, considered that the spraying of various tree fruits with weak solutions of indolylacetic acid at the time of flowering (50, 25 or 12·5 mg. per litre) and again 3 or 4 weeks later at the time of fruit setting (10, 5 and 2·5 mg. per litre) and thereafter at intervals of 10 to 14 days until 5 sprays had been applied in all, resulted in more fruits being set and considerably increased yields. The treatments were said to be especially effective with apricots ; but the author considered that much further investigation would be necessary before the treatment could be recommended for use on a commercial scale.

Swarbrick (1945) sprayed trees of two varieties of apple after a severe frost, which had occurred when the young fruitlets were already beginning to grow, and which killed the embryos and blackened the centres of the young fruits. The spray used contained 5 p.p.m. indolylbutyric acid, 5 p.p.m. α-naphthaleneacetic acid, 5 p.p.m. 2,4-dichlorophenoxyacetic acid and 60 p.p.m. β-naphthoxyacetic acid, giving a total growth substance content in the solution of 75 p.p.m. This treatment had little effect on the fruit of Cox's Orange Pippin, one of the varieties treated, but with the other variety, Miller's Seedling, the fruits remained on the trees and showed appreciable swelling, whereas practically all the young fruits dropped from unsprayed trees. Later the fruits stopped growth, but many of them attained a diameter of from 1½ to 2 inches. Swarbrick considered that these results gave encouragement to the hope that substances which would be fully effective for improving fruit set and development in deciduous fruits would eventually be found. Lewis (1946) concludes that the growth substances at present in use are only likely to cause parthenocarpic development of many-seeded fruits.

Luckwill (1946b) pointed out that in the apple, fruit size and shape is considerably affected by the number and position of fertile seeds present, and suggested that the developing seed might be the source of substances which control the development of the fruit. He was successful in obtaining an extract from young apple seeds which was effective in causing the development of seedless tomato fruits, when applied to the ovaries of emasculated tomato flowers. Swarbrick (1945) had succeeded in obtaining an extract active in the same way from tomato flowers. Woodcock (1947) identified the crystalline substance obtained by Luckwill from apple seeds as phloridzin and stated that this substance is present in quantities as great as 8 per cent. of the fresh seed weight up to four weeks after petal fall and decreases to less than 1 per cent. after 8 weeks. The relationship between this substance and the hormone obtained from the same source, which stimulates the growth of unfertilized tomato ovaries, has still to be worked out.

7. Citrus.

Pomeroy and Alrich (1943) applied α-naphthaleneacetic acid, indolylacetic acid, indolylbutyric acid, furacrylic acid and calcium furoate to the flowers of Washington Navel orange and Marsh grapefruit. The treatments did not increase the percentage of flowers setting fruit.

8. Date Palm.

Nixon and Gardner (1939) attempted to influence the development of the ovaries of date palms by applying growth substance preparations, but were unsuccessful.

9. Pineapples.

Clark and Kerns (1943) studied the effect of the α-naphthaleneacetic acid sprays on the fruit development of pineapple plants at Honolulu. It was found that only the application of such relatively high concentrations as 0·5 per cent. produced a marked increase in the size and weight of the fruit. The average weight of treated fruit in one experiment was 5·98 lb. as against 5·27 lb. for untreated fruit. These high concentrations of growth substance retarded ripening by about a week, however, and inhibited slip and sucker growth.

V. THE CHEMICAL COMPOSITION OF ARTIFICIALLY PRODUCED PARTHENOCARPIC FRUITS COMPARED WITH THAT OF NORMALLY POLLINATED FRUITS

Gustafson (1941a) found that, although the growth rate of fruits produced parthenocarpically under the influence of growth substance treatments was greater in the early stages of development than that of normally pollinated fruit, it tended to be less during later stages possibly because of a lower hormone content, but later Gustafson (1942c) found that seedless fruits produced with β-naphthoxyacetic acid were larger than seeded fruits produced by normal pollination.

Janes (1941) studied the chemical composition of parthenocarpic tomato fruits produced by the application of indolylbutyric acid or indolylacetic acid, as compared with normally pollinated seeded fruits. The titratable acidity in both parthenocarpic and seeded fruits was very similar during development, except for a short period during ripening, when the seeded fruits gave higher values. The acid was distributed evenly throughout the parthenocarpic fruits, but the seeded fruits were lower in acid in the outer wall and higher in the locular region. As the fruits matured, sugar increased, in all regions of the parthenocarpic fruits, more rapidly than in the normal fruits. It is evident that the developing seeds exert a considerable influence on the chemical composition of the fruit. Janes (1942) also compared the chemical composition of parthenocarpic pepper fruits produced with indolylbutyric acid with normally produced seeded fruits. On a dry weight basis, all the constituents determined, with the exception of nitrogen, which was about 0·25 per cent. higher in the parthenocarpic fruits, showed no marked differences between the two types of fruit, regardless of the stage of development at which they were studied. The dry weight of ripe red parthenocarpic pepper fruits was from 1 to 2 per cent. higher than that of the normal seeded fruits.

Mitchell and Whitehead (1942) produced a high percentage of seedless tomato fruits by fumigating the plants with vaporized β-naphthoxyacetic acid when the flowers were opening. It was found that the vitamin C content of such fruits was quite equal to that of fully seeded fruits grown under similar environmental conditions.

Pollard, Kieser and Steadman (1945) found that parthenocarpic tomato fruits induced by growth substance treatments were sweeter and somewhat insipid in taste as compared with normal pollinated fruits, presumably owing to the fact that their sugar content was higher whereas their titratable acidity was about the same as in normal fruits. There was no marked difference in total solids in the two types of fruit. The ascorbic acid content was about the same in both, unless high concentrations of hormones had been used to produce the seedless fruit, in which case it was somewhat lower in these.

VI. FRUITFULNESS AND NATURAL HORMONES

Apart from the artificial production of parthenocarpic fruit by the external application of growth substances there may also be a positive correlation between the natural fruitfulness of a variety and the internal hormone content of its blossoms. Thus, Gustafson (1939a) found that the auxin content in the ovaries from varieties of oranges, lemons and grapes that are prone to produce seedless fruits was higher than in the ovaries of corresponding varieties that do not produce fruit parthenocarpically. Gustafson (1942b), also, collected blossom buds that were about to open, from different groups of Montmorency cherry varieties which were known to have high and low bearing tendencies. It was found that the buds from the fruitful trees had more than three times as large a natural hormone content as buds from barren trees. He concluded that there is a positive correlation between fruit setting and the internal growth hormone content of the ovaries of the flowers.

VII. STIMULATION OF POLLEN DEVELOPMENT

Smith (1942) found that indolylacetic acid, indolylbutyric acid and α-naphthaleneacetic acid stimulated the growth of pollen tubes. Pollen of *Antirrhinum majus* and *Bryophyllum daegremontianum* was used and the tests were carried out at a temperature of 25° C. Indolylacetic acid and indolylbutyric acid were more effective than α-naphthaleneacetic acid. Vitamin B_1 gave no stimulation and colchicine at concentrations of about 1 : 100,000 retarded both germination of the pollen grains and tube elongation. Addicott (1943) found that, of 33 substances tested, 16 had a stimulating effect on the germination and pollen tube growth of the pollen of *Tropaeolum majus* and *Milla biflora*. It was also considered, as a result of this work, that pollen germination and tube growth are two distinct physiological processes requiring different factors, since it was found that some of the substances tested affected one of these processes, but not the other.

VIII. STIMULATION OF OVULE DEVELOPMENT

Overbeek, Conklin and Blakeslee (1941a) found that the injection of a 0·1 per cent. solution of the ammonium salt of α-naphthaleneacetic acid into the young ovaries of a tetraploid *Melandrium* variety, induced the formation of parthenocarpic fruits with well enlarged placentas and ovules which developed seed coats and nucellus, but no embryo. If applied to the outside of the ovary or peduncle, ovary but not ovule development resulted. Similar effects were also obtained using *Datura stramonium* as the test plant.

IX. INCREASING THE SET OF HAND-POLLINATED FLOWERS

In plant breeding work, where hand pollination is carried out, difficulty is sometimes experienced in obtaining a satisfactory percentage of flowers to set. Some investigational work has been carried out to determine the possibility and effectiveness of applying supplementary growth substance treatments, to improve the number of fruits developing following artificial pollination. The object in this work is not, of course, the production of parthenocarpic fruits, but to obtain a higher percentage of normal fruits containing viable seeds.

Burrell and Whitaker (1939) obtained encouraging results using indolylacetic acid to increase the effectiveness of hand pollination of the muskmelon (*Cucumis melo* L.). Whitaker and Pryor (1946), however, failed to obtain satisfactory results using indolylacetic acid, indolylpropionic acid, indolylbutyric acid, naphthaleneacetamide, α-naphthaleneacetic acid, β-naphthoxyacetic acid, several phenoxy compounds and pollen extracts. A significant increase in the set of fruit was obtained, however, by using 4-chlorophenoxyacetic acid. In two experiments with this substance the percentage set of treated flowers was 26 and 60 as compared with 7 and 27 per cent. respectively, for flowers receiving hand pollination only. The chemical was applied at a concentration of 10 mg. per g. lanolin, and the most effective method of application was found to be that of detaching the corolla where it joins the ovary and applying the paste to the torn surface.

X. THE SOURCE OF THE HORMONE IN RELATION TO THE DEVELOPMENT OF THE FRUIT

Muir (1942) made direct measurements of diffusible growth hormones from styles and ovaries of pollinated and unpollinated flowers of *Nicotiana tabacum*. Very small amounts were obtained from the portions of an unpollinated pistil, but considerable quantities were found in the portions of a pollinated pistil. The hormone concentration found was closely related to the extent of penetration of the pollen tubes into the style and fertilization resulted in the release of large amounts in the ovary. The pollen grains and pollen tubes were not thought to be the actual source of these hormones but it was suggested that the pollen tubes might secrete an enzyme which can liberate the active growth hormones from inactive forms or precursors in the style and ovary.

XI. HISTOLOGICAL STUDIES

Gardner and Kraus (1937) found that the development of parthenocarpic fruits in holly after the application of indolylacetic acid followed much the same course as that of pollinated fruits. The chief differences were that the cells of the stigmas of the fruits induced by spraying with the growth substance proliferated more than those of the pollinated ones and that suberization was considerably slower. There was no embryo or endosperm development in the induced fruits.

Beal (1943) made an intensive histological study of the development of the ovaries of *Lilium regale* following treatment with 1 per cent. mixtures of indolylacetic acid, α-naphthalene-acetic acid and β-naphthoxyacetic acid in lanolin. A 1 per cent. mixture of all three substances together was also used. The pastes were applied directly to the cut surface of the ovary, after removing stamens, stigma and style. There was very little difference in the response obtained under the influence of the various substances used. The increase in size of the ovaries following treatment resulted from the enlargement of cells composing the carpels and the outer integuments of the ovules. Certain regions of the carpel walls, the inner integuments and the nucellus shrunk and collapsed relatively early in development.

Young (1943) also made a histological study in comparing the development of cucumber fruits following normal pollination, developing without pollination, and developing following treatment with growth substances. A variety (Rollinson's Telegraph) which exhibits natural parthenocarpy was used for this study.

XII. SOME ADDITIONAL METHODS

A. Irradiation.

Withrow (1945), working with tomato plants grown during the winter season, when days were short and conditions cloudy with low light intensities, found that irradiation caused an increased fruit set on the first five clusters of the Long Calyx variety. The total fruit production from clusters beyond the fifth, however, was less than from comparable clusters on the control plants. Much the same effect was obtained using the variety Michigan State Forcing. The net result of the treatment was, however, a slight gain in the number and weight of fruit picked from the plants receiving the irradiation treatment. The irradiation treatment of the plants was begun when the cotyledons were unfolding and the plants were given a four-hour daily treatment from 6.30 p.m. to 10.30 p.m. with illumination from a 300 watt internal reflector lamp, suspended 24 inches above the tops of the plants. The treatment was continued for a total of 21 days. After this period the plants were transplanted to their fruiting quarters and given no further irradiation. Other groups of plants were treated with an emulsion containing indolylbutyric acid at 0·2 g. per 100 mls. ; here also fruit production was increased by the treatment. From the results obtained it was suggested that the irradiation of the young plants, followed by treatment of the flowers of the first clusters with growth substances might have given still better yields.

B. Fluorescein.

Liu and Lou (1945) induced the development of parthenocarpic fruits in cucumber by applying a lanolin paste containing 1 per cent. fluorescein to the stigma and cut styles of the female flowers. Smaller, seedless, parthenocarpic fruits were later also induced in luffa, eggplant and pepper by a similar treatment.

THE USE OF GROWTH SUBSTANCES AS SELECTIVE WEED KILLERS

I. EARLY WORK.

From the earliest work with plant hormones and synthetic growth substances it was soon apparent that overdoses can cause injury and even death of plant tissues. For example, in using these substances to induce root formation in cuttings, it is well known that doses above the optimum can easily cause severe injury to the cuttings ; moreover this toxic dosage varies with the species of cutting and the growth substance used, and is to some extent selective. Slade, Templeman and Saxton (1945) state that in tests carried out at Jealott's Hill Research Station, England, in 1940, applications of α-naphthaleneacetic acid at the rate of 25 lb. per acre to oats (*Avena sativa* L.), among which, yellow charlock (*Brassica sinapis visiana*) was growing, killed the charlock but only slightly retarded the growth of the oats. Other laboratory experiments showed that wheat, barley and rye had similar resistance to oats, but that greater plantain (*Plantago major* L.) and yarrow (*Achillea millefolium* L.) were susceptible like charlock.

Experiments with many other different chemicals followed and in 1941 it was shown that 4-chloro-2-methyl-phenoxyacetic acid was active in depressing the germination and early seedling growth of corn buttercup (*Ranunculus arvensis* L.), fat hen (*Chenopodium album* L.) corn marigold (*Chrysanthemum segetum* L.), corn spurrey (*Spergula arvensis* L.) and field poppy (*Papaver rhoeas* L.), at concentrations which had little effect on the growth of cereals. The sodium salt of the acid suppressed germination and killed plants of yellow charlock at any stage from young seedlings to flowering plants when applied at the rate of 10 mg. per sq. foot (approximately 1 lb. per acre), and a field trial, carried out in **1943** with application at the same rate, completely eradicated yellow charlock from a field of spring oats, without damaging the cereal.

Zimmerman and Hitchcock (1942b) described the effects of a series of phenoxy compounds on plants and showed them to cause striking formative effects, even at extremely low concentrations. One of the most active of these chemicals was 2,4-dichlorophenoxyacetic acid, and in America this compound has since received much investigation as a selective weed killer. Marth and Mitchell (1944) investigated the use of 2,4-dichlorophenoxyacetic acid as a differential herbicide. They applied aqueous sprays of the acid in concentrations of from 250 to 1,000 p.p.m. and found the treatment to be successful in killing seedlings of dandelion, narrowleaf plantain, white clover, chickweed, pigweed, wood-sorrel, knotweed, broad-leaf dock, bindweed and shiny pennywort. Other plants such as broadleaf plantain, sheep's sorrel, daisy, yarrow and *Rubus* spp. were relatively resistant. The spray was applied to established Kentucky bluegrass sod, without apparent injury and bluegrass seed planted under a light top-dressing of soil was also sprayed and the grass seed germinated and became established without injury. Hamner and Tukey (1944a) sprayed field mixtures of common weeds with 2,4 dichlorophenoxyacetic acid at 1,000 p.p.m. and Carbowax 1,500 at the rate of 1 part of the acid to 5 parts of Carbowax. Bindweed, narrow-leaf plantain, dandelion, round-leafed mallow, lamb's quarters and ragweed were killed. Pigweed, milkweed, tomato, broad-leafed plantain, Pennsylvania smartweed, purslane, chickweed and red clover showed responses including twisting of the leaves, swelling of the stems and roots and splitting of the stems and killing of a percentage of the plants. There were no visible effects on quick grass, Kentucky bluegrass, yellow foxtail, green foxtail, wild oats, large crab grass, small crab grass, barnyard grass and goosegrass.

II. ACTIVE GROWTH SUBSTANCES AS HERBICIDES

A. Substances already used in practical weed control.

The two substances which have been most widely used in practice as selective weed killers are 2,4-dichlorophenoxyacetic acid (2,4-D) in America and 2-methyl-4-chlorophenoxyacetic acid in England. Both these compounds are of great value in controlling and eradicating broad-leaved weeds from cereal crops and from lawn grasses, as they kill the weeds at concentrations which do little harm to the crops.

B. Some other active substances.

Thompson, Swanson and Norman (1946) investigated the activity of nearly eleven hundred different substances, and compared their activity with that of 2,4-dichlorophenoxyacetic acid in laboratory and glasshouse tests. The comparison was made by investigating their activity in inhibiting the growth of the primary root of germinating maize seeds, and in inhibiting the growth of young kidney bean plants. The activity of the substances tested was expressed as a percentage of the inhibition caused by 2,4-dichlorophenoxyacetic acid used at the same concentrations. Some of the most active substances in the maize root test were as follows :—

2,4-dichlorophenoxyacetic acid	100
2-bromo-4-chlorophenoxyacetic acid	101
4-(2′,4′-dichlorophenoxyacetamido)-2,5-dichlorobenzene sulphonic acid (Na salt)	100
2,4-dichlorophenoxyacetic anhydride	102
2,4-dichlorophenoxyacetic 4′-sulphoanilide	104
2,4-dichlorophenoxyacetyl chloride	107
2,4-dichlorophenoxyacetyl guanidine	101
β-(diethylamino)-ethyl 2,4,-dichlorophenoxyacetate	100
β-(diethylamino)-ethyl 2,4,5-trichlorophenoxyacetate	104
2,2-dimethyl-1,3-dioxalane-4-methanyl-2′-methyl-4′-chlorophenoxyacetate	100
1,4-di-(2′,4′,5′-trichlorophenoxyacetamido)-benzene	100
N-(2,4-dichlorophenoxyacetyl)-urea	99
2-methyl-4-chlorophenoxyacetamide	103
2-methyl-4-chlorophenoxyacetic acid	114
2-methyl-4-chlorophenoxyacetic anhydride	101
2-methyl-4-fluorophenoxyacetic acid	107
N-methyl-2,4,5-trichlorophenoxyacetamide	103
Phenyl chloroacetate	102
2,4,5-trichlorophenoxyaceto-2′,4′,6′-trichloranilide	102

Swanson (1946c) compared the activities of several substances applied as sprays in oil solutions to the leaves of young soybean plants. By this method it was found that derivatives of 2,4,5-trichlorophenoxyacetic acid produced a greater inhibiting effect than either 4-chloro derivates or 2,4-dichlorophenoxyacetic acid at the same concentrations.

C. Substances inhibiting growth of cereals and grasses, relatively inactive on some broad-leaved species.

Slade, Templeman and Sexton (1945) state that preliminary experiments carried out in 1940 showed that ethyl-phenylcarbamate applied at the rate of 50 mg. per square foot to oats sown with charlock affected the growth of the oats but not that of the charlock. Subsequently the activity of about fifty related arylcarbamic esters and thiocarbamates was examined. It was then found that N : N-Di(carboethoxyaniline) had an activity about equal to that of ethyl-phenylcarbamate, whilst isopropyl-phenylcarbamate was very active, being nearly three times as potent as ethyl-phenylcarbamate.

It was found that isopropyl-phenylcarbamate applied in concentrations which stopped the growth of cereals did not affect the growth of marigold, sugar beet, flax, rape and yellow charlock. It even arrested the growth of established cereal plants in flower when applied at higher concentrations, and applied to rye at 30-50 mg. per square foot, when the ears were just appearing, resulted in the formation of heads containing no grain.

Allard, Ennis, De Rose and Weaver (1946) compared the activity of isopropyl-phenylcarbamate with that of some of the phenoxy compounds. It was also found that when isopropyl-phenylcarbamate was applied in aqueous solution to soil at rates of 1½ to 6 mg. per 4 inch pot of soil, seedlings of oats, wheat, corn, barley and rice were killed or severely stunted, whereas similar concentrations of 2,4-dichlorophenoxyacetic acid and other phenoxy acids did not inhibit the growth of these plants. When applied to the soil of pots containing soybeans, kidney beans, cowpeas, sunflowers, radishes, turnips and sugar beets isopropyl-phenylcarbamate did not inhibit their growth at the same concentration.

III. METHODS OF APPLICATION

The commonest methods of applying the hormone herbicides has up to the present been by the use of sprays or dusts. Recent work has, however, held out the possibility of incorporation in the soil at sowing time for certain purposes. The aerosol method has also been used, but mainly for small scale experiments.

A. The solution spray method.

1. Preparation of Solutions.

Marth and Mitchell (1944) prepared their spray solutions of 2,4-dichlorophenoxyacetic acid by dissolving the required amount of the acid in Carbowax 1,500 (a polyethylene glycol), and then adding this solution with stirring to the required amount of tap water. The carbowax, as well as being a good solvent for the active chemical, also acted as a carrier and spreading agent and was usually used in amounts sufficient to give a 0·5 per cent. solution in the completed spray mixture.

The ammonium salt of the acid has also been used and this can be prepared in aqueous solution, if desired, as it is considerably more soluble than the acid. Templeman (1945) and Blackman (1945) have used the sodium salt of 4-chloro-2-methylphenoxyacetic acid.

2. Rate of Application.

Marth and Mitchell (1944) and Hamner and Tukey (1944) used 2-4-dichlorophenoxyacetic acid or its salts at concentrations ranging mainly from 500 to 1,000 p.p.m. Many weeds were killed at this concentration, e.g. wood-sorrel (*Oxalis* sp.), chickweed (*Stellaria media*) pigweed (*Amaranthus retroflexus*), knotweed (*Polygonum aviculare*) and morning glory (*Convolvulus sepium*). Other weeds such as ox-eye daisy (*Chrysanthemum leucanthemum* var. *pinnatifolium*), yarrow (*Achillea millefolium*), broad-leaf plantain (*Plantago major*), sheep's sorrel (*Rumex obtusifolius*) and *Rubus* spp. recovered from a single application of 1,000 p.p.m. but could be killed by repeated sprays. The rate of application was usually 4 gallons per 1,000 sq. feet.

Slade and Templeman (1945) and Blackman (1945) applied sprays of sodium 4-chloro-2-methylphenoxyacetic acid for killing a number of weeds and for eradicating weeds from cereal crops at the rate of 1 lb. of active substance per acre in 100 gallons/acre of water. This gave effective control of yellow charlock (*Brassica arvensis*), white charlock (*Raphanus raphanistrum*), pennycress (*Thlaspi arvense*) corn buttercup (*Ranunculus arvensis*) and other weeds. Some species such as parsley piert (*Alchemilla arvensis*), and fat hen (*Chenopodium album*) were, however, somewhat resistant.

There are now many proprietary preparations on the market incorporating these active substances, and practical growers will probably find it most convenient to purchase one of these and apply it according to the instructions supplied by the manufacturers.

Smith (1946) stressed the importance of droplet size in conjunction with rate of application and concentration of the solution in obtaining the maximum kill of plants when using 2,4-dichlorophenoxyacetic acid as a herbicide. He considered that the greatest efficiency was attained, as measured by the effect on kidney bean plants, by sprays of relatively large droplet size (561-250μ per average diameter) applied at a volume rate of 10 to 20 ml. per sq. yard.

3. Addition of Carriers and Wetting Agents.

Mitchell and Hamner (1944) found that the use of carbowax compounds (polyethylene glycols) as carriers and wetting agents for preparing aqueous solutions of 2,4-dichlorophenoxyacetic acid increased the effectiveness of the chemical. Tests showed that Carbowax 1,500 to a final concentration of 0·5 per cent. was not toxic to kidney bean plants.

Beal (1944a and b) applied 2-chlorophenoxyacetic acid, 4-chlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid and 2,4,6-trichlorophenoxyacetic acid as solutions to plants of sweet pea, African marigold and red kidney bean plants using both Carbowax 1,500 and lanolin, as carriers. He found that the effectiveness of the active chemical used varied somewhat with the carrier employed. For most of the phenoxy compounds tested carbowax was better than or equal to lanolin, but 4-chlorophenoxyacetic acid was an exception, in that plant responses were much greater when lanolin was used as a carrier.

Ennis and Boyd (1946) found that the addition of any of three Carbowaxes 1,500, 1,540 and 4,000 at a concentration of 0·5 per cent. enhanced the activity of 2,4-dichlorophenoxyacetic acid in inhibiting the growth of kidney bean plants. When soybeans were used as the test plants, however, the addition of the waxes did not make very much difference to the responses obtained. They recommended that in many cases it might be preferable to use the ammonium salt of 2,4-dichlorophenoxyacetic acid as a herbicide, because, on account of its greater solubility, aqueous sprays can easily be prepared, and thus the extra cost of adding the relatively expensive Carbowaxes is rendered unnecessary.

Hopp and Lindner (1946) found that under conditions of low humidity the addition of glycerol to the herbicidal spray prevented the solution from drying so quickly on the leaves and thus increased the effectiveness and killing properties of the herbicides. Substances used in these tests included sodium trichlorophenoxyacetate and sodium pentachlorophenoxyacetate.

4. Testing the Activity of Solutions.

Swanson (1946b) considered that low concentrations of 2,4-dichlorophenoxyacetic acid could be assayed by the effect of the substance in inhibiting the growth of the primary root of germinating maize. A hybrid field maize, var. Silver King (Wisconsin No. 7) was used as the test plant. The seeds were first sterilized by dipping in a saturated solution of sodium hypochlorite for three minutes, and were then germinated on moist filter paper in Petri dishes, in a dark room maintained at a constant temperature of 26° C., for 48 hours. At the end of this time seedlings with primary roots of length between 15 and 25 mm. were selected and placed in 6 inch Petri dishes on filter paper moistened with 15 ml. of the solution to be tested. The seedlings were then allowed to grow on for a further 48 hours in the constant temperature darkroom. The degree of inhibition of the primary root was expressed as a percentage of the growth obtained in pure water. From a calibration curve obtained with known concentrations of 2,4-dichlorophenoxyacetic acid, it was considered that unknown concentrations ranging from 0·01 to 2·0 p.p.m. could be accurately determined by this method.

B. The dust method.

Templeman (1946), in testing the herbicidal action of 2-methyl-4-chlorophenoxyacetic acid, stated that as the result of trials carried out between 1943 and 1945 it had been established that very good results could be obtained by applying the active chemical in dust form. The carrier used consisted of finely powdered dry chalk and was used at the rate of 2 cwt. per acre, containing from 2 to 8lb. of the herbicide, according to the weeds to be controlled. It was found that roughly twice as much of the weed killer was required in the dust as in solution to obtain about the same effect. Thus where sprays were used at the rate of 1 lb. of chemical per acre in 100 gallons of solution, the dust would be used at 2 lb. per acre in 2 cwt. of powdered chalk. It was pointed out that the dust would be of special value where the conveyance of large quantities of water to grain lands might be a drawback to the use of the solution spray method.

Marth, David and Mitchell (1945) carried out experiments to test the effectiveness of 2,4-dichlorophenoxyacetic acid as a herbicide when applied in a dust carrier. The chemical was applied to various species of weeds growing in a greenhouse ; various kinds of carriers were used and in some tests water-absorbing agents were also added to the mixtures. Finely ground Pyrax, fuller's earth, " Cherokee " clay and talc were used as carriers and the dust mixtures were prepared by dissolving the desired amount of the acid in 95 per cent. alcohol, and then stirring this solution into the dust carrier to make a smooth paste (1 ml. per 1 g. carrier). This paste was then dried in an oven at 80 ° C., and when dry, repulverized to form the fine dust mixture ready for use. In the dusts containing water-absorbing agents 3 per cent. by weight of either glycerine or Carbowax 1,500 was used. The addition of these agents was said to result in a dust that was slightly sticky but which nevertheless could be readily applied. In other mixtures, calcium chloride in a finely ground state was mixed with the dust, just before application. The dusts were applied at a rate of approximately 4 lb. of mixture per 1,000 square feet using a small mechanical dusting machine.

All the carriers used were equally effective. Dusts containing 10 per cent. of the acid, killed heal-all (*Prunella vulgaris*), pennywort (*Hydrocotyle rotundifolia*) and ribwort plaintain (*Plantago lanceolata*).

This concentration was also effective in eradicating clover from bluegrass turf, but the grass was severely injured ; almost complete eradication (99 per cent.) was, however, obtained using a 5 per cent. dust and with this only very slight injury to the grass occurred. A 2·5 per cent. dust killed 85 per cent. of the clover without injury to the grass.

The addition of either 3 per cent. Carbowax 1,500 or glycerine to the dust mixtures markedly increased its killing power. Thus with these hygroscopic agents added, a 0·05 per cent. dust killed plants of morning glory (*Ipomoea lacunosa*) and a 0·5 per cent. dust killed plants of ragweed (*Ambrosia bidentata*) and lamb's quarters (*Chenopodium album*) whereas similar dusts without their addition did little injury to the same plants when used at the same concentration of active chemical. Calcium chloride was relatively ineffective used in this way.

They advise caution in using the dusts in practice in avoiding injury to adjacent plants by drift, and warn the operators to avoid breathing in the dusts.

C. The aerosol method.

Hamner and Tukey (1944b) prepared aerosols using 2 per cent. of 2,4-dichlorophenoxyacetic acid in 10 per cent. motor oil (S.A.E. 30) and 88 per cent. dimethyl ether.

They claimed that the use of aerosols was the most rapid killing and most effective treatment tested. Its action was considerably more quickly effective than spray treatment.

D. Application to the soil.

Templeman (1946) and Allard, De Rose and Swanson (1946) found that applying dressings of 2-methyl-4-chlorophenoxyacetic acid or 2,4-dichlorophenoxyacetic acid to the soil in appropriate amounts prevented the establishment of many broad-leaved plants and weeds, but merely retarded the growth of cereals such as wheat, oats and barley. Allard, De Rose and Swanson (1946) applied either of the acids at the rate of 3 mg. to 1 lb. of soil, and then sowed seeds of kidney bean, soybean, turnip, oats, wheat and barley. The germination of the broad-leaved plants was entirely prevented, but the cereals merely showed stunted growth.

Isopropyl-N-phenylcarbamate given at the same rate had just the opposite effect and prevented the establishment of the cereals without affecting the germination and growth of the broad-leaved plants. Mixture of both types of compound therefore hold out promise of being of much value as a general herbicide for killing most plants and for clearing land.

IV. SENSITIVITY OF VARIOUS WEED PLANTS TO 2,4-DICHLOROPHENOXYACETIC ACID AND 4-CHLORO-2-METHYLPHENOXYACETIC ACID OR THEIR SALTS

Prepared from lists given by Slade, Templeman and Sexton (1945), Blackman (1940), Marth and Mitchell (1944), Hamner and Tukey (1944), Greenwood and Doak (1946), Warren (1946), Wood and Olson (1947), and Moore (1947).

GROUP 1. SPECIES READILY KILLED.

Acer negundo	Manitoba Maple
Alternanthera denticulata	Lesser Joyweed

GROUP 1. SPECIES READILY KILLED—*continued.*

Amaranthus retroflexus	Red-root
Amaranthus spp.	Pigweeds
Ampelopsis quinquefolia	Virginia Creeper
Anagallis arvensis	Scarlet Pimpernel
Arctium minus	Burdock
Artemisia sp.	Wormwood
Barbarea sp.	Cress
Bellis perennis	Daisy
Brassica adpressa	Buchan Weed
Brassica arvensis	Yellow Charlock
Brassica campestris	Field Cabbage
Brassica tournefortii	Wild Turnip
Calystegia sepium	Greater Bindweed
Calystegia turgoriorum	
Capsella bursa-pastoris	Shepherd's Purse
Carduus nutans	Nodding Thistle
Carduus tenuiflorus	Winged Thistle
Carthamus lanatus	Saffron Thistle
Centaurea calcitrapa	Star Thistle
Centaurea cyanus	Cornflower
Centaurea melitensis	Maltese Cockspur
Centurea solstitialis	Yellow Star Thistle
Chenopodium album	Lamb's Quarters or Fat Hen
Chenopodium carinatum	Keeled Goosefoot
Chenopodium multifidum	Scented Goosefoot
Cirsium lanceolatum	Scotch Thistle
Conium maculatum	Hemlock
Convolvulus arvensis	Field Bindweed
Convolvulus erubescens	Australian Bindweed
Convolvulus sepium (=*Calystegia sepium*)	Greater Bindweed
Coronopus didymus	Hog-cress
Crassula sieberiana	Crassula
Cymbonotus lawsonianus	Bear's Ear
Daucus carota	Wild Carrot
Dichondra repens	
Echium plantagineum	Patterson's Curse
Equisetum arvense	Field Horsetail
Erechtites quadridentata	Cotton Fireweed
Erigeron linifolius	Flax-leaved Fleabane
Erodium circutarium	Stork's-bill
Erodium cygnorum	do.
Erophila vulgaris	Whitlow Grass
Erysimum cheiranthoides	Treacle Mustard
Erythraea australis	Australian Centaury
Euphorbia peplus	Petty Spurge
Foeniculum vulgare	Fennel
Galeopsis tetrahit	Hemp Nettle
Galinsoga cilita	Galinsoga
Goodenia pinnatifida	Goodenia
Grindelia squarrosa	Gumweed
Helianthus spp.	Sunflowers
Hydrocotyle sp.	Pennywort
Hypochaeris radicata	Cat's Ear
Iva xanthifolia	False Ragweed

GROUP 1. SPECIES READILY KILLED—*continued.*

Lactuca scariola	Prickly Lettuce
Lamium amplexicaule	Henbit
Lappula echinata	Blue Burr
Lepidium hyssopifolium	Pepperwort
Lepidium spp.	
Lithospermum arvense	Corn Gromwell
Lupinus arboreus (young plants)	Tree Lupin
Malva parviflora	Small-flowered Mallow
Malva rotundifolia	Dwarf Mallow
Marrubium vulgare	Horehound
Medicago arabica	Spotted Medick
Medicago denticulata	Burr Medick
Medicago minima	Small Woolly Burr Medick
Medicago lupulina	Black Medick
Medicago sativa	Lucerne
Melilotus spp.	Sweet Clovers
Papaver hybridum	Rough Poppy
Papaver rhoeas	Corn Poppy
Plantago lanceolata	Ribwort
Plantago major	Greater Plantain
Plantago varia	Small Plantain
Polycarpon tetraphyllum	Four-leaved Allseed
Polygonum pennsylvanicum	Smartweed
Populus tremuloides	American Aspen
Portulaca oleracea	Purslane
Potentilla spp.	Cinquefoils
Prunella vulgaris	Self-heal
Ranunculus arvensis	Corn Buttercup
Ranunculus repens	Creeping Buttercup
Raphanus raphanistrum	White Radish
Reseda luteola	Wild Mignonette
Salvia verbenacea	Wild Sage
Scandix pecten-veneris	Venus Comb
Setaria spp.	Foxtails
Silene gallica	French Catchfly
Silybum marianum	Variegated Thistle
Sisymbrium orientale	Indian Hedge Mustard
Solanum opacum	Black-berried Nightshade
Sonchus arvensis	Corn Sowthistle
Sonchus oleraceus	Common Sowthistle
Stachys arvensis	Stagger Weed
Taraxacum officinale	Dandelion
Thlaspi arvense	Pennycress or Stinkweed
Tribulis terrestris	Caltrop
Urtica dioica	Common Nettle
Urtica urens	Small Nettle
Verbascum virgatum	Twiggy Mullein
Veronica arvensis	Field Speedwell
Veronica hederaefolia	Ivy-leaved Speedwell
Veronica tournefortii	
Vicia spp.	Vetches
Xanthium orientale	Cockleburr
Xanthium spinosum	Bathurst Burr

GROUP 2. RELATIVELY RESISTANT, ALTHOUGH GROWTH IS RETARDED.

Achillea millefolium	Yarrow
Alchemilla arvensis	Parsley Piert
Asparagus officinalis	Asparagus
Asperula conferta	Woodruff
Chondrilla juncea	Skeleton Weed
Chrysanthemum spp.	
Cirsium arvense	Californian Thistle
Chrysostemma calendulaceum	Cape Weed
Cyperus rotundus	Nutgrass
Epilobium glabellum	Smooth Willow-herb
Fumaria officinalis	Fumitory
Hypericum perforatum	St. John's Wort
Iva axillaris	Poverty Weed
Lactuca pulchella	Blue Lettuce
Lycium ferocissimum	African Box Thorn
Matricaria chamomilla	Chamomile
Matricaria inodora	Scentless Mayweed
Modiola caroliniana	Red-flowered Mallow
Nasturtium palustre	Marsh Watercress
Oenothera biennis	Evening Primrose
Polygonum aviculare	Wireweed or Knotgrass
Polygonum convolvulus	Wild Buckwheat or Black Bindweed
Polygonum persicaria	Lady's Thumb or Persicaria
Polygonum prostratum	Creeping Knotweed
Polygonum spp.	Knotweeds
Portulaca oleracea	Purslane
Rhus toxicodendron	Poison Ivy
Rumex acetosella	Sheep's Sorrel
Rumex brownii	Swamp Dock
Rumex crispus	Curled Dock
Rumex spp.	Docks
Salix spp. (variable)	Willows
Salsola pestifer	Russian Thistle
Spergula arvensis	Spurrey
Spergula rubra	Sand Spurrey
Trifolium repens	White Clover
Ulmus americana	White Elm
Verbascum thapsus	Great Mullein

GROUP 3. VERY RESISTANT.

Acaena ovina	Sheep's Burr
Agropyron repens	Quack grass or Couch.
Agrostis tenuis	Brown Top
Asclepias spp.	Milkweeds
Bulbine bulbosa	Bulbine Lily
Cardaria draba	Hoary Cress
Centaurea repens	Russian Knapweed
Cotula australis	Common Cotula
Cucumis myriocarpus	Paddy Melon
Danthonia spp.	Wallaby Grass
Datura stramonium	Common Thornapple
Echinochloa crus-galli	Barnyard Grass
Euphorbia drummondii	Caustic Weed
Euphorbia esula	Leafy Spurge

Group 3. Very Resistant—*continued.*

Fraxinus spp.	Ash
Galium aparine	Cleavers
Hordeum jubatum	Wild Barley or Squirrel-tail Grass
Hordeum leporinum	Barley Grass
Linaria vulgaris	Toadflax
Lolium perenne	Perennial Ryegrass
Lomandra spp.	Lomandra
Lychnis alba	White Campion
Oxalis corniculata	Yellow Wood Sorrel
Phalaris tuberosa	Phalaris
Poa pratensis	Kentucky Bluegrass
Poterium sanguisorba	Salad Burnett
Rosa spp.	Wild Rose
Rubus spp.	Blackberry
Setaria sp.	Foxtails
Silene latifolia	Bladder Campion
Silene noctiflora	Night-flowering Catchfly
Stellaria media	Chickweed
Tragopogon porrifolius	Salsify
Tricoryne elatior	Tricoryne
Trifolium arvense	Mare's Foot Clover
Trifolium dubium	Yellow Suckling Clover
Trifolium glomeratum	Clustered Clover
Trifolium repens	White Clover
Trifolium subterraneum	Subterranean Clover
Typha angustifolia	Bullrush or Lesser Reedmace
Vinca major	Periwinkle
Viola spp.	Violet
Vittadinia triloba	New Holland Daisy

The majority of grasses and most evergreen species are resistant.

These lists can only serve as an approximate guide, as the category into which a species is placed depends to a considerable extent upon the conditions under which the test is carried out. Thus young plants are usually more readily killed than older plants, and the effectiveness of the sprays depends to a considerable degree on the temperature and growth conditions when applications were made. These factors probably explain the disagreement between various observers in classing the susceptibility of some of the species.

V. SENSITIVITY OF CROP PLANTS

Templeman (1946) considered that one of the most important uses of 2-methyl-4-chlorophenoxyacetic acid and its salts was as a means of controlling weeds in cereal crops. He found that solution sprays at the higher concentrations were more liable to damage the cereal crops than dry dusting, and that late sprays (after crop was more than 15 inches high) were more damaging than early ones. Winter wheat, spring oats, spring barley and grasses were found to be resistant or only slightly injured by the weed killer. Turnips, kale and other brassicas, sugar-beet, marigolds, lucerne, onions and field beans were very susceptible and were very severely injured or killed by light applications. Potatoes, however, were resistant to light dressings.

Barrons and Grigsby (1945) reported that pea plants were severely injured by sprays of 2,4-dichlorophenoxyacetic acid and Warren (1946) using sodium salt of the same acid at 1,000 p.p.m. reported that carrots (Red Cored Chantenay), onions (Southport Yellow Globe); beets (Perfected Detroit); peas (Thomas Laxton); cabbage (Wisconsin Hollander) and lima beans (Henderson Bush) were all killed by the sprays.

Weaver, Swanson, Ennis and Boyd (1946) carried out investigations to determine at what stage of development different varieties of crop plants were most sensitive to " hormone " herbicidal preparations. The ammonium salt of 2,4-dichlorophenoxyacetic acid in aqueous spray form was used. Some of the more important results obtained were as follows: with cabbage sprayed at three growth stages, namely 6 to 8 leaves, beginning to head, and with heads 4 inches in diameter, the herbicide at rates of 0·3 to 3 lb. per acre killed plants in the two younger stages, but the older plants were only very slightly affected. Soybeans were sprayed at 4 stages of development, using the ammonium salt at the rate of 0·5 lb. per acre. At the stage when the seedlings were 3 inches or 6 inches high considerable growth retardation and distortion occurred, but the plants recovered later and gave good yields. At later stages such as early flowering and with pod formation starting, the plants showed less immediate response, but yields of beans were considerably reduced. Soil applications at rates of 3, 10 and 20 lb. per acre reduced yields considerably when application was made at planting time, but had little effect on established plants at any growth stage.

Tomato plants were sprayed at rates of 0·1 and 1·0 lb. per acre. Young plants (8 to 12 inches high) were injured and sometimes killed but, if still alive, they recovered well and the subsequent yield of fruit was only slightly reduced. When treated in early bloom no fruit set, and if treated at the early fruiting stage yields were greatly reduced and the fruit formed was often of poor shape. Sugar beet plants were killed with application at the rate of 0·5 lb. per acre, at all stages studied, and sweet potato plants were killed with applications at rates of 0·25 and 1·0 lb. per acre during young growth stages, and at later stages, although susceptibility decreased with increasing age and size of plant, the root yields were greatly reduced.

These results at least hold out the hope that when more information has been gathered, the growth substance herbicides will find some use in the cultivation of these more susceptible crop plants, and will be able to be used at certain growth stages.

VI. SOME PRACTICAL USES OF GROWTH SUBSTANCE WEED KILLERS

A. Control of weeds in cereal crops.

Slade, Templeman and Sexton (1945) carried out extensive field experiments with sodium-4-chloro-methyl-phenoxyacetate applied as a spray at the rate of 1 lb. in 100 gallons of water per acre or as a dust with china clay or chalk as a diluent at the rate of 2 lb. per acre and found that by this means weeds such as yellow charlock, white charlock, corn buttercup, pennycress, fat-hen, corn marigold, corn spurry and field poppy were successfully eradicated from cereal crops. Templeman (1946) stated that in most cases spraying when the crop was more than 15 inches high caused more damage to the cereals than earlier treatments, except application prior to emergence of the seedlings. Barley seemed slightly more liable to damage than either wheat or oats.

Shafer, Hamner and Carlson (1946) sprayed maize 8 to 10 inches high with 2,4-dichlorophenoxyacetic acid at 1,000 p.p.m. and containing 0·5 per cent. Carbowax 1,500. Good weed control was obtained without injury to the maize. In other tests, maize was sprayed when it was just starting to tassle and at this stage fairly severe injury often resulted. The applications at the young seedling stage were therefore much the best and successfully killed weeds such as bindweed, field mustard, pigweeds, lamb's quarters, ragweed and burdock.

B. Treatment of lawns.

1. Rates of Application and Weed Control.

Mitchell, Davis and Marth (1944) carried out tests to determine the use of 2,4-dichlorophenoxyacetic acid for eradicating weeds from lawns. Good control of such weeds as dandelion and plantain was obtained by applying the acid or its sodium or ammonium salts at the rate of about 1½ lb. per acre. At this dosage the growth of most of the common lawn grasses in well established turf was not appreciably affected. Marth and Mitchell (1946) found that one application of 2,4-dichlorophenoxyacetic acid at a concentration of 1,000 p.p.m. and sprayed at the rate of 5 gallons per 1,000 square feet of lawn completely eradicated dandelion (*Taraxacum officinale*) and plantain (*Plantago lanceolata*). A subsequent application of as little as 125 p.p.m. killed plantain seedlings that germinated after the first treatment, and a year after the treatment 96 per cent. elimination of dandelion and 99 per cent. elimination of plantain was evident. The rate of growth of the grass in a mixed turf was reduced somewhat for 10 to 14 days after applying either the free acid at 1,000 p.p.m. or its ammonium salt at 1,500 p.p.m., but after recovery the grass produced from 15 to 80 per cent. more leaf growth than untreated patches due to the elimination of the weeds. Pridham and Cornman (1946) also found that dandelions, plantains and other common weeds could be eliminated from lawns by spraying with an emulsion of 2,4-dichlorophenoxyacetic acid or a solution of one of its salts. They suggested that new lawns are best allowed to grow to one inch in height before spraying, and that the best and quickest control of the weeds is obtained if the lawn is sprayed when the weeds are growing actively. The spray should not be applied in a strong wind for fear of drift injuring nearby plants.

Marth and Mitchell (1946a) also examined the possibility of adding fertilizers to the spray to stimulate the growth of the grass at the same time as controlling the weeds. They found that the addition of urea at the rate of 60 lb. per acre had no effect on the herbicidal properties of the spray and resulted in 40 to 130 per cent. more grass in a 2 month period. Ninety pounds of urea was injurious to the grass. In other tests the fungicide Fermate was added to the weed killer at the rate of 2 lb. per 100 gallons and had no apparent effect on its herbicidal properties.

2. Effect on the Growth of the Grass.

Mitchell and Marth (1945) carried out experiments to determine the effect of applications of 2,4-dichlorophenoxyacetic acid on the growth of grass at various stages. Tests were designed to examine the effect on the emergence and subsequent growth of the grass when the acid was applied to the soil just after sowing the seed, and also the effect of spraying established grass plants. Seeds of Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis alba*) and red fescue (*Festuca rubra*) were planted in pots and the soil was then sprayed with a water mixture containing 0·1 per cent. of 2,4-dichlorophenoxyacetic acid and 0·5 per cent. Carbowax 1,500 at rates equivalent to $\frac{3}{4}$, $1\frac{1}{2}$, $2\frac{1}{4}$ and 3 lb. of the acid per acre. At the heavier rates of application, $2\frac{1}{4}$ and 3 lb., the number of seedlings of all three grasses that emerged was reduced as compared with untreated soil. Redtop was more sensitive that the other two grasses, and even the lower rates of application, $\frac{3}{4}$ lb. and $1\frac{1}{2}$ lb. per acre affected its emergence. On the other hand the number of seedlings of fescue and bluegrass emerging was slightly increased by the light applications. The subsequent growth of the seedlings that emerged was retarded at first, but, judged by the weight of the clippings, recovery was complete after from 5 to 11 weeks at the $\frac{3}{4}$ and $1\frac{1}{2}$ lb. per acre dosages. At the heavier rates of application growth was still retarded after 14 weeks. Seeds planted in the same soil 5 weeks after treatment however, germinated and grew normally.

Turf consisting of a mixture of the same three grasses and growing in the open was also sprayed at the same rates of application ($\frac{3}{4}$ to 3 lb. per acre.). Although the grass appeared normal, growth was somewhat reduced for a period of 1 to 2 months but its growth was equivalent to that of unsprayed turf after this period. Farnham and Hallowell (1946) and Pridham (1946) also reported that the application of 2,4-dichlorophenoxyacetic acid at the time of sowing the seed resulted in poorer germination of most grasses. Application to young or established grass however, resulted in good weed control and should be used in conjunction with a good fertilizer application to encourage the growth of the grass.

C. Control of weeds in sugar-cane.

Overbeek, Gregory and Vélez (1946) showed that a single application of a 0·075 per cent. aqueous solution of 2,4-dichlorophenoxyacetic acid eradicated *Commelina longicaulis* Jacq., and a 0·3 per cent. solution eradicated *Cyperus rotundus* L., from cultivated sugar-cane plantings, and, moreover, at these concentrations the acid was harmless to the growth of the sugar-cane plants.

It was not considered that the use of the herbicide would entirely do away with cultivation, however, because after susceptible weeds had been killed their place was usually taken by grasses which were resistant to the spray. On the other hand the weeds which were killed are not usually removed by hand hoeing, so that for satisfactory weed control in sugar cane, they considered a combination of spraying and cultivation would probably achieve the best results.

D. Possible use in nurseries.

Beatly and Jones (1945) observed the effects of Weedone (a proprietary preparation containing 2,4-dichlorophenoxyacetic acid) at a concentration of 1 part to 100 parts of water applied as a spray to a large number of annuals, perennials and young and old shrubs growing in a nursery. The object was to determine if the preparation could be used for the selective weeding of nursery stock. Most of the plants were either killed, however, or temporarily damaged. *Iris kaempferi*, gladiolus, delphinium (2 vars.), *Aquilegia canadensis*, Regal Lily, *Doronicum*, *Veronica spicata*, violets (2 vars.), *Phlox subulata*, *Ligustrum* (2 vars.), *Deutzia gracilis*, *Taxus cuspidata* and many varieties of older conifers and shrubs were, however, uninjured. It was concluded that susceptible plants should be protected when the spray is used for weed killing.

E. Control of woody plants.

Hamner and Tukey (1946) found that the water soluble sodium salt of 2,4-dichlorophenoxyacetic acid applied by spraying at a concentration of 2,000 p.p.m. during a warm period (80-85° F.), in the early spring (April) at the time of leaf emergence, resulted in the death of chokeberry (*Prunus virginiana* L.), honeysuckle (*Lonicera canadensis* Marsh) poison ivy (*Rhus toxicodendron*) sumac (*Rhus typhina* L.), hawthorn (*Crataegus* spp.) and elm (*Ulmus americana* L.), three weeks from the date of application. No effect was apparent on juniper (*Juniperus communis* L.). When the spray was applied during a period of cool weather (below 50° F.) in late April, the treated plants did not die until the occurrence of a warm period in June, and 50 per cent. of the poison ivy plants recovered. In other tests ointments containing 20 per cent. of 2,4-dichlorophenoxyacetic acid were applied to the cut surfaces of the stem and resulted in the deaths of the tops of virginia creeper, grape, willow chokeberry and honeysuckle, but not of hawthorn.

F. Possible use for weeding potatoes.

Ennis, Swanson, Allard and Boyd (1946) tested the effect of the following substances, applied as either aqueous or oil emulsion sprays on the growth of potatoes :—2,4,5-trichlorophenoxyacetate, 2,4,5-trichlorophenoxyacetylchloride, 2-methyl-4-chlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid, *p*-chlorophenoxyacetic acid, 2-bromo-3-nitrobenzoic acid, 2,3,5-tri-iodobenzoic acid, 2-methyl-4-6-dichlorophenoxyacetic acid, isopropyl-phenylcarbamate 2,5-dichlorophenoxyacetic acid, 2,4-dibromophenoxyacetic acid, 2,5-dimethylphenoxyacetic acid, 3-chlorophenoxyacetic acid, 3,5-dichlorophenoxyacetic acid, 3,4-dichlorophenoxyacetic acid, 2,3,5-trichlorobenzoic acid and butyl 2,4-dichlorophenoxyacetic acid.

Potato plants sprayed with the ammonium salts of 2,4-dichlorophenoxyacetic acid and 2-bromo-3-nitrobenzoic acid in water solutions, developed epinastic responses soon after treatment but fully recovered in a few days. When used as oil-containing sprays, 2-methyl-4-chlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid caused a reduction in the yield of tubers. In aqueous sprays, however, none of the compounds except 2,4,5-trichlorophenoxyacetate caused much injury to the foliage. These results were therefore considered to hold out the promise of the possible utilization of some of these compounds for the selective control of weeds in potato fields. More work still needs to be carried out, however, before making practical recommendations.

G. Control of water weeds.

It was found by Hildebrand (1946) that 2,4-dichlorophenoxyacetic acid or its salts in concentrations of from 1 in 800 to 1 in 1,700 applied as a spray at the rate of 1 gallon to 100 to 150 square feet of weed-filled water, gave very good eradication of the water hyacinth, which is a serious pest in many sub-tropical regions. Small fish were apparently quite uninjured by the treatment.

H. Control of pollen production.

Smith, Hamner and Carlson (1946) found that water sprays of 2,4-dichlorophenoxyacetic acid at 1,000 p.p.m., applied at early stages of flower development, prevented pollen shed in plants of *Ambrosia artemisiaefolia* and *Ambrosia trifida*.

I. Treatment of soil and manure to destroy weed seeds.

Hamner, Moulton and Tukey (1946b) found that treatment of compost and manure with 10 to 100 p.p.m. of 2,4-dichlorophenoxyacetic acid prevented weed seed from germinating.

Four weeks after treatment, however, bean and pea seed germinated and grew normally when dressed with the treated manure. Grass seeds, although more resistant, could also be destroyed. The fact that treated manure or soil is usable in a relatively short period after treatment suggests that it may be a useful and easy method for sterilizing seed beds and for treating compost and manure, which is to be used as top dressing for lawns and for other purposes. Pridham (1947) considered that 2,4-dichlorophenoxyacetic acid used at rates of 15 to 75 lb. per acre at the time of ploughing gave promise of eradicating the rhizomes of perennial grasses and other weeds which easily regenerate.

J. Control of weeds in strawberry plantations.

Carlson (1947) examined the possibility of using sprays of 2,4-dichlorophenoxyacetic acid to weed strawberries. He considered that a spray containing 1,000 parts per million of the acid might safely be applied to newly planted strawberry plantations which were not to be cropped the first year, but in the second year spraying could only be carried out after harvest of the fruit because of the liability of the spray to damage blossoms and fruits.

K. Control of weeds in gladioli.

Krone and Hamner (1947) obtained good control of weeds with no injury to the gladioli plants by applying 2,4-dichlorophenoxyacetic acid at rates from 2 to 20 lb. per acre to the soil three weeks before setting out the bulbs. The spray could not, however be applied to growing plants as damage resulted.

VII. THE PERSISTENCE OF GROWTH SUBSTANCE WEED KILLERS IN THE SOIL

When the growth substance weed killers are used for clearing land of weeds, it is obviously of great importance to know how long their effect persists in the soil and at what time after application it is safe to plant susceptible crops on treated land. For example, Martin (1946) stated that 2,4-dichlorophenoxyacetic acid was very toxic to citrus roots and that the limit of tolerance of citrus seedlings to the acid in the soil was found to be about 4 p.p.m. on a dry soil basis, and even as little as 1 p.p.m. could exert a considerable toxic effect.

De Rose (1946) studied the rapidity with which 2,4-dichlorophenoxyacetic acid was leached out of the soil. It was found that small amounts of the acid were readily leached from pots of soil by amounts of water equivalent to 1·5 and 3·0 inches of rain. When amounts such as 100 mg. in 2,500 g. of soil were present, however, the equivalent of 4·5 inches of rain was necessary before young tomato seedlings could safely be planted in the treated soil. Normal plants could be grown in greenhouse soil, 8 weeks after treatment of the soil with the weed killer at the rate of 12 mg. to 1 lb. of soil.

In field trials, as determined by their action on young soybean plants, which are, however slightly more resistant than tomato plants, 2,4-dichlorophenoxyacetic acid did not persist in damaging concentrations for more than 80 days nor isopropyl-N-phenylcarbamate for more than 60 days. 2-methyl-4-chlorophenoxyacetic acid seemed to persist rather longer, for with application at the rate of 50 lb. per acre enough remained after 68 days to be toxic to soybeans, whereas with the same rates of application the effects of 2,4-dichlorophenoxyacetic acid and isopropyl-N-phenylcarbamate had disappeared in the same time. When applied at 10 and

20 lb. per acre 2,4,5-trichlorophenoxyacetic acid also retained its herbicidal activity longer than 2,4-dichlorophenoxyacetic acid.

Mitchell and Marth (1946) mixed 2,4-dichlorophenoxyacetic acid in various amounts with batches of soil, some of which were then stored in a dry state and some were stored moist. Samples of soil from the various series were then taken at various times after treatment and planted with seeds of mustard, barley and annual morning glory, to determine the effect on their germination and growth. It was found that in air dry soil the acid was very slowly inactivated, and that such soil containing 1 mg. or more of the acid per lb. of soil, still reduced the percentage germination of mustard seeds even after 18 months' storage. With the more resistant barley seeds low concentrations of the acid did not significantly affect its germination after one month's storage of the dry soil and even soil which originally contained 14 mg. per 1 lb. soil did not actively retard the growth of barley seedlings after 6 months' storage.

When moist soil, high in organic matter, was mixed with as much as 20 mg. of 2,4-dichlorophenoxyacetic acid per 1 lb. soil and stored under moist warm conditions, the effect of the acid disappeared much more quickly. Thus, after two weeks under such conditions, mustard seeds could be planted in the soil without there being any detrimental effect either on their germination or the subsequent growth of the seedlings.

Hanks (1946) treated samples of 6 widely different soils namely, sandy with pH 3·8, silt loam with pH 7·7, peaty with pH 6·7, clay loam with pH 8·4, sandy loam with pH 7·1 and sandy clay with pH 8·4, with lime and with 2,4-dichlorophenoxyacetic acid or its calcium salt. Thus there were four different treatments for each soil type, namely (1) lime with the acid, (2) lime with the calcium salt, (3) the acid without lime and, (4) the calcium salt without lime. Samples of the treated soils from each series were then leached with water at rates equivalent to 10 and 16 surface inches over a six week period, and the relative toxicity of the leachate was determined by the retardation of the growth of maize roots. These tests indicated that leachates from the peat soil were relatively non-toxic after two weeks, and those from all the others except the sandy clay pH 8·4, at the end of six weeks. The addition of lime appeared to have little effect on the relative toxicity of the leachates.

Germination tests, using red kidney bean seed as the test plant were also carried out with samples of soil from each treated series after the six week period.

These showed that all the soils were free, by that time, from the toxic effect of the acid, except the sandy clay with the high alkalinity (pH 8·4).

It is evident that the rate at which the toxic effect of the growth substance disappears from soils depends mainly on the temperature and moisture conditions in the soil and one can therefore expect the most rapid disappearance under warm moist conditions, and it is also fortunate that under such conditions these herbicides exert their greatest effect as weed killers.

VIII. THE RELATION OF TEMPERATURE AND GROWTH RATE TO HERBICIDAL ACTION

It has been the experience of most workers who have used the growth substances as weed killers that their action is most rapid when prevailing conditions are warm and when the plants sprayed are in a stage of most active growth.

Marth and David (1945) made a special study of these relationships. They grew early winter cress (*Barbarea verna*) and narrow-leaved plantain (*Plantago lanceolata*) plants, in 4-inch clay pots at a temperature which varied only within the range 65° F. to 75° F. until they were all well established. Various batches of plants were then removed to greenhouses maintained at temperatures of (1) 32° F. to 40° F., (2) 50° F. to 65° F., (3) 65° F. to 75° F. and, (4) 75° F. to 90° F. respectively. Separate lots of each series of plants were then sprayed with solutions of 2,4-dichlorophenoxyacetic acid at concentrations of 500, 1,000 and 1,500 p.p.m. and other batches were kept unsprayed or sprayed with water only as controls. Carbowax 1,500 at a concentration of 0·5 per cent. was included in the spray mixtures.

When the treatments were applied to the plants growing at temperatures of 65° F. to 75° F. or at 75° F. to 90° F., all three concentrations used were of about equal effectiveness and rapid killing of the plants took place (18 to 21 days). When the plants were growing at temperatures of 50° F. to 60° F., killing required from 29 to 36 days and at temperatures of 32° F. to 40° F., treated plants of both the test species were still alive 50 days after the spray applications were made. Determinations showed, however, that the growth substance was present either on or in the tissues of these plants, and such plants died fairly quickly when removed to higher temperatures.

Field experiments were also carried out in which dormant, narrow-leaved plantain plants, bearing a few living leaves and growing in frozen ground, were sprayed with 2,4-dichlorophenoxyacetic acid or its sodium salt at concentrations of 1,000 p.p.m., with applications at the rate of 5 gallons per 1,000 square feet.

These plants were not killed rapidly under these conditions but when later they were placed under warmer conditions favouring growth killing was also rapid.

IX. EFFECT OF RAIN COMING SOON AFTER APPLICATION

The question as to whether rain coming soon after application of the weed-killing sprays reduces their effectiveness is an important practical point. Weaver, Minarik and Boyd (1946) made a special study of this aspect and found that heavy rain falling immediately after the application of 2,4-dichlorophenoxyacetic acid, in oil containing sprays, did not result in any lessening of the response of soybean and red kidney bean plants. When an aqueous solution of the more soluble ammonium salt of the acid was applied, however, response was often considerably decreased if the rain fell within 24 hours after the application. This effect also naturally depends to some extent on temperature and growing conditions, for it was found that under greenhouse conditions no lessening of response occurred, if artificial " rain " was applied more than 6 hours after the same spray application. They considered, however, that the use of an oil carrier for the herbicide would probably be a distinct advantage and well worth the extra cost, when using the sprays in regions subject to frequent heavy rainfall.

X. SOME PRECAUTIONS TO OBSERVE IN USING GROWTH SUBSTANCE WEED KILLERS

A. Avoid overdoses.

It must be remembered that these growth substance sprays are very potent, and that their selective action is relative to the concentration used. At too high concentrations, even cereal and grass plants are liable to be seriously damaged. It is therefore imperative that the solutions and spray mixtures should be carefully prepared and ingredients accurately measured. If a proprietary preparation is used, the makers' directions should be carefully followed, for damage of valuable crops might result from failure to observe this precaution. Black (1947) as the result of trials carried out in New Zealand, stressed the importance of obtaining even distribution of hormone weed killers if the best results are to be obtained, and suggested that further research on this aspect is very desirable. Modification of spray equipment to obtain an even flow may perhaps be necessary.

B. Danger of drift and damage to nearby plants.

The spray or dust should be kept as far as possible only on the area which it is desired to treat. This is especially important when using herbicides on lawns, where there is considerable danger of drift falling on valuable plants and hedges nearby, with fatal results, and under such conditions treatment should not be attempted when strong winds are prevailing. With mixtures containing highly volatile spreaders, there is even greater danger of damaging plants in the neighbourhood. For example, Staten (1946) concluded that the sprays could do much damage to cotton crops growing near areas where such sprays had been used. He concluded that under such conditions it was much safer to use a mixture containing 2,4-dichlorophenoxyacetic acid alone. Cotton is apparently very sensitive to even small traces of the herbicide, especially when the crop is in very active growth.

It is also important to choose the time of application for weed killing in crop plants, so that the crop is in a relatively resistant stage of growth and the weeds in a susceptible stage as far as is possible.

C. Danger of residual effects from contaminated spray equipment.

Probably the safest procedure, where possible, is to keep special spray equipment which is used solely for the application of the herbicides. This ideal procedure will often be impossible and in such cases it is very important that the spray equipment should be thoroughly cleaned, before using it for the application of fungicidal and insecticidal sprays or valuable plants may be severely injured. For example Johnson and Ritcher (1946) found that insufficient cleaning of spray equipment in which 2,4-dichlorophenoxyacetic acid had been used, often left enough material to cause severe injury to plants of tomato, cabbage and pepper, subsequently sprayed with insecticidal and fungicidal sprays from the same equipment. Wood and Olsen(1947) recommended a thorough washing of equipment with a solution of washing soda after using the weed killers as the safest procedure.

Marsh and Taylor (1947) reported fairly severe injury to apple trees through applying a summer oil spray, utilizing a spray system which had been previously used to apply a 2,4-dichlorophenoxyacetic acid spray for the eradication of poison ivy. Although the spray system had been well rinsed with water, fairly severe damage to trees of the Winesap, Stayman and Northern Spy varieties occurred, whereas trees of the York, Gano and Turley varieties were relatively resistant. Bryant, Vincent and Schafer (1947) also noticed malformations in the fruit of Jonathan and Delicious apples obtained from orchards in which 2,4-dichlorophenoxyacetic acid sprays had been used to eradicate bindweed. In this case the damage was thought to have been caused either by drift or even actual intake of the acid by the roots of the trees.

XI. THE RESPONSE OF PLANTS TO GROWTH SUBSTANCES USED AS HERBICIDES

A. Effect on growth, seed germination and seedling development.

Marth and Mitchell (1944) described the action of 2,4-dichlorophenoxyacetic acid applied in lethal concentrations to susceptible growing plants. They pointed out that the growth substance does not cause rapid superficial burning, like sulphuric acid or other toxic weed killers, but that it brings about morphological and physiological responses at the point of application or in parts of the plant at some distance from the actual point of contact, by active translocation in the tissues. Growth responses usually occur soon after treatment (24 hours) and apparently before the concentration of the acid or products formed from it have reached a lethal level. These responses are characterized by much distorted stem and leaf growth and inhibition of bud growth, especially the terminal ones, and sometimes also by the production of galls and thickened roots on the main stem. These responses are followed later by the disintegration of the cells and tissues and death of the plant. As has already been noted, there are very great differences in the sensitivity of even closely related species of plants to the active compounds.

Nutman, Thornton and Quastel (1945) found that the action of 2,4-dichlorophenoxyacetic acid varied, according to the concentration used, from complete inhibition of germination and development to a stunting of the root system and a dwarfing of the leaves. Allard, De Rose and Swanson (1946) studied the development of seeds of kidney beans, soybeans, peas, korean lespedeza, turnips, radishes, rutabagas, sugar beets, sunflowers, cotton, muskmelons, cucumbers, buckwheat, maize, wheat, oats, rice, sorghum, barley and millet. The laboratory test employed consisted in placing 25 seeds upon four layers of filter paper moistened with 100 ml. of test solutions, contained in glass dishes. The dishes were then kept in a dark room maintained at a temperature of 25° C. to 27° C. and the seedlings observed daily for 4 days. Concentrations varying from 0·01 to 100 p.p.m. were used. In general, germination was delayed and seedling development was abnormal, the severity of the effect depending on the concentration of the solution and the species used. With maize the effect of a solution of isopropyl-N-phenylcarbamate was compared with that of four chlorophenoxyacetic acids and was found to cause less reduction in seedling growth than the phenoxy compounds.

Taylor (1946a and b) studied the effect of various amounts of 2,4-dichlorophenoxyacetic acid added to the nutrient solutions of plants growing in water cultures. Maize, soybean, wheat, oat, rice and kidney bean plants, growing in a modified Hoagland's nutrient solution were used in the tests. It was found that the growth of broadleaved plants was decreased by concentrations of 2,4-dichlorophenoxyacetic acid as low as 0·15 p.p.m. in the nutrient solution and that soybean plants were killed in 8 to 10 days in solutions containing from 1 to 5 p.p.m. Cereal plants remained alive after 20 days in solutions containing from 0·5 to 3·0 p.p.m. of the acid, although dry weight production was considerably reduced. Wheat was slightly more resistant than maize as determined in this way. Taylor (1946c and d) also kept plants for a certain time in nutrient solutions containing 2,4-dichlorophenoxyacetic acid and removed them at various intervals to a plain nutrient solution. In this way it was found that the treatment of soybean plants for just over two days, in a solution containing 5 p.p.m. of the acid, was sufficient to kill them, whereas the treatment of cereal plants for 7 days in a solution of similar concentration only resulted in diminished growth and was not lethal. Taylor also compared the action of 2,4-dichlorophenoxyacetic acid with that of isopropyl-phenylcarbamate added to water cultures of wheat plants. Although used in this way both substances were toxic to the plants, the appearance of the plants in the two series was markedly different. The shoots of those treated with isopropyl-phenylcarbamate withered and died, whereas the shoots of the plants treated with 2,4-dichlorophenoxyacetic acid remained alive, but became dark green, highly cutinized and leathery. As is usually the case with any toxic substance, Taylor found that effects were much more pronounced in water cultures than in soil cultures, when equivalent concentrations were applied.

Weaver (1946) sprayed plots of young red kidney bean plants with dilute, non-lethal concentrations of 2,4-dichlorophenoxyacetic acid at rates of 0·1, 0·01 and 0·001 g. per square yard. The fresh weights of the tops of the plants were decreased, and the two higher concentrations used caused a reduction in the dry weight of the roots of the kidney bean plants. The two weaker sprays caused an increase in the weight of the roots of soybean up to 16 days after application of the sprays, but the differences disappeared later. The shoot to root ratio was reduced in all treatments on the soybean but not with the kidney bean plants. Pod formation was decreased by all treatments.

B. Histological responses.

Swanson (1946a), using kidney bean plants, found that meristematic tissues and tissues capable of becoming meristematic were most readily affected by 2,4-dichlorophenoxyacetic acid. Thus the greatest activity was induced in the endodermis, in the pericycle fibres, in the phloem parenchyma and in the medullary rays. The formation of vascular bundles in the endodermis and in the phloem was not stimulated by the action of 2,4-dichlorophenoxyacetic acid and in this respect its action differed from that of other growth substances such as indolylacetic acid.

Beal (1946) studied the histological effects of four phenoxy compounds, applied to the second internode of decapitated bean plants and also found that responses occurred chiefly in the endodermis, cambium, phloem and ray parenchyma.

Strickler (1946) determined the effect of the ammonium salt of 2,4-dichlorophenoxyacetic acid on the gametophyte of *Pteris longifolia* and found that growth was inhibited, mainly by inhibition of cell division : there was little effect on cell enlargement.

C. Absorption and translocation in the plant.

Weaver and De Rose (1946) using young *Coleus* and *Nasturtium* plants found that spray solutions were as effective when only the side of the leaf without stomata was wetted, as when the stomata-bearing side was treated. Stomata did not therefore appear to be very important as sources of entry of the solutions.

Great stunting of plants (red kidney bean) occurred when the herbicide was applied to the youngest parts of the plants. The growth substance readily passed downward through the plant and the velocity of movement was apparently greatly influenced by the photosynthetic activity and the age of the tissue.

Mitchell and Brown (1946) considered that, when applied to the leaves of kidney bean plants, the translocation of 2,4-dichlorophenoxyacetic acid was closely associated with that of organic food materials and apparently occurred as a continual flow, confined to the living cells or parenchyma. When applied to the roots, the stimulus was translocated through dead portions of the stem, which indicated that the substance was probably translocated in the transpiration stream.

D. Effect on carbohydrate reserves.

Mitchell and Brown (1945) sprayed plants of morning glory (*Ipomoea lacunosa* L.) growing in a glasshouse, with a solution containing 1,000 p.p.m. of 2,4-dichlorophenoxyacetic acid and 0·6 per cent. of Carbowax 1,500. Under conditions either favourable or unfavourable for growth carbohydrate reserves (starch and dextrose) were rapidly depleted in flower buds and roots. Sugar content increased slightly over that of control plants at first and was then rapidly reduced. Depletion of carbohydrates, therefore, was apparently an important factor in causing the death of the plants.

Tukey, Hamner and Imhofe (1945) working with plants of bindweed (*Convolvulus arvensis* L.) and sow thistle (*Sonchus arvensis* L.) sprayed with 2,4-dichlorophenoxyacetic acid found that in bindweed the pollen grains were disorganized, flowers arrested in development, chlorophyll formation checked and cell division greatly increased, in all cambium regions of the stem and rhizome. Leaf cells were plasmolysed and, going hand in hand with these changes, starch disappeared rapidly from flowers, from stems and from rhizomes.

E. Effect on transpiration and respiration.

Brown (1946) sprayed bean seedlings with 2,4-dichlorophenoxyacetic acid at a concentration of 1,000 p.p.m. It was found that treated plants transpired 34 per cent. less water than unsprayed plants during the first 5 days after spraying and were dead within 7 days.

Respiration increased 19 to 80 per cent. in bean plants 24 hours after spraying, whilst plants of morning glory (*Ipomoea lacunosa*) sprayed at flowering time, showed an 80 per cent. increase in respiration on the fourth day after treatment.

Solid matter in the tops decreased in response to sprays containing 1,000 p.p.m. of the acid, but increased in the basal regions of the stem, if more dilute sprays were used.

Moisture content increased in the stems and in the plants as a whole but decreased in the leaves.

It was concluded that the most serious effects of 2,4-dichlorophenoxyacetic acid on the plants was depression of the rate of leaf expansion and interference with the metabolism and the normal transport of food materials.

BUD INHIBITION AND SOME PRACTICAL APPLICATIONS

I. INTRODUCTION

It has long been known that an actively growing terminal bud on a shoot suppresses the development of lateral buds lower down on the same shoot. If this actively growing terminal bud is removed, however, some of the lateral buds soon begin to grow out. Horticulturists constantly make use of this fact in producing bushy plants, by pinching out the growing points of shoots. Various explanations, mainly of a nutritional nature, were put forward by early investigators to explain this inhibiting action of the terminal bud ; but Snow (1925) was the first worker to bring forward strong evidence for the presence of a special inhibiting substance. Skoog and Thimann (1934), using plants of *Vicia faba* (broad bean), removed the terminal buds of young plants and placed an agar block containing auxin on the decapitated stump ; in this way it was found that the auxin could replace the action of the terminal bud in inhibiting the growth of the lateral buds below. Later it was found that pastes containing pure indolylacetic acid were also active in the same way. The exact mechanism by which the inhibition is brought about is still a matter of some controversy. Thimann (1939) gives a good review of the subject and discusses in full some of the theories that have been brought forward. The fact that synthetic growth substances can under certain conditions cause bud inhibition has, however, led to some applications of importance in practice and these are considered below.

II. INHIBITING SPROUT DEVELOPMENT IN POTATO TUBERS

Guthrie (1938) soaked the basal portions of cut pieces of potato tubers in solutions of neutralized indolylacetic acid for from 1 to 10 days, at a temperature of 10 C. The concentration of the solutions used ranged from 25 mg. to 100 mg. per 100 ml. water. These treatments effectively inhibited the sprouting of the pieces of tuber and also induced some root formation at the cut surfaces.

In later papers Guthrie (1939a and b) found that the methyl ester of α-naphthaleneacetic acid also inhibits the growth of the buds of potato tubers and is, moreover, sufficiently volatile at room temperature (22° C to 25° C.) to allow it to be introduced into intact tubers in vapour form. The sprouting of whole tubers could therefore be retarded merely by storing them in the presence of paper impregnated with this substance. The growth of the buds was also successfully inhibited by storing the tubers in a paper bag, the inside of which had been sprayed with a solution of the same chemical. Guthrie (1939b) also compared the inhibiting action of several substances on potato bud growth and found that α-naphthaleneacetic acid was more than 10 times as effective as indolylacetic acid at the same concentration.

Denny (1942) reported further experiments on the prevention of sprouting in potato tubers by means of growth substances. Tubers were exposed to action of the vapour of the methyl ester of α-naphthaleneacetic acid, in wooden bins, various batches being treated at different times from October to May. Paper towels were impregnated with the chemical and then distributed among the tubers, to give a dosage of 100 mg. of the ester per kilogramme of tubers. Investigation showed that the tubers retained not more than 5 mg. of the substance per kilogramme of tissue and of this amount at least 80 per cent. was present in the peel. Dormancy induced by the action of this substance was found to be even more profound than that which occurs during the natural rest period of the tubers. Some of the treated tubers showed some damage, consisting of hard lumplike excrescences, which were apparently formed by the enlargement of underlying tissue. The treated tubers germinated poorly when planted in soil, but the induced dormancy could be broken by treatment of the tubers with ethylene chlorohydrin, in the same way as it is used for breaking the natural dormancy during the normal rest period.

Denny, Guthrie and Thornton (1942) impregnated filter papers with the methyl ester of α-naphthaleneacetic acid, and then placed these amongst potato tubers stored in glazed earthenware containers, at a rate which gave a dosage of 400 mg. of the active chemical to one kilogramme of tubers. This treatment completely inhibited sprouting for at least a year, when the temperature was maintained at 10° C. and, moveover, at this temperature no shrinkage of the tubers occurred. When the temperature was kept at 15° C. sprouting was inhibited for 8 months, but there was some shrinkage due to loss of moisture from the tubers. At 18° C. and at 23° C. sprouting was successfully inhibited for from 3 to 6 months but a good deal of shrivelling occurred, due to more rapid loss of moisture at these higher temperatures. The treatment appeared to have very little effect on the sugar content of the tubers.

Van Stuivenberg and Veldstra (1942) carried out experiments in Holland and found that spraying potato tubers with a solution of methyl α-naphthaleneacetate in March or at the time when the tubers were just beginning to show signs of sprouting, resulted in the inhibition of sprouting for some months after treatment. These treated tubers kept well and did not shrink and wilt like untreated tubers. Earlier treatment, by spraying in December and January, when the tubers were completely dormant, was not so effective in delaying sprouting and, moreover, necessitated the use of considerably stronger solutions of the chemical.

Thomas and Riker (1945) found that the treatment of potato tubers stored at a temperature of 70° F. with methyl α-naphthaleneacetate effectively prevented sprouting. The most effective procedure consisted in applying the chemical either in a dust carrier and dusting the tubers with this mixture, or by distributing shredded paper, in which the chemical was absorbed, amongst the tubers. In either case the most effective dosage appeared to be application at the rate of 0·9 g. of the active substance per bushel of potatoes. Some of the treated tubers, especially of the Cobbler variety, developed hard knobbly growths particularly in the area around the buds, and in extreme cases these growths cracked open and blackened on the surface; but tubers in which this happened did not appear to decay more readily than other tubers. The growth substance treatment had no effect on the blackening of tubers which sometimes occurs when they are cooked.

Smith (1946) also described the use of the methyl ester of α-naphthaleneacetic acid for preventing or retarding sprout formation in potato tubers in storage, and stated that the chemical could be applied impregnated in shredded paper, carried in inert dusts, sprayed, in solution form, on tubers in bins, or the tubers could be treated by the aerosol method. In any case, however, the dosage should be from 0·9 to 1·0 grammes of the chemical per bushel of tubers. For spray treatment the substance is dissolved in a small quantity of methyl alcohol and applied as the relatively concentrated solution, and for aerosol treatment one part of the chemical is used with 9 parts of methyl chloride. The impregnated filter paper or dust treatments are probably the most convenient methods for treating small quantities of tubers in domestic and other small stores.

III. INHIBITING SPROUT DEVELOPMENT IN OTHER VEGETABLES

Van Stuivenberg (1946a) treated onions with the methyl ester of α-naphthaleneacetic acid in an attempt to retard sprouting in storage. The onions showed a distinct tendency to rot after treatment and practical recommendations could not be made without further investigation. Smith (1946) however, considered that the treatment of carrots, turnips and beetroots with this substance might prove of practical use for storage purposes.

IV. RETARDING THE OPENING OF BUDS ON INTACT PLANTS

A. Delaying the opening of buds of deciduous fruit trees so as to escape frost injury.

Hitchcock and Zimmerman (1938) stated that the growth of flower and leaf buds on fruit trees could be delayed by the application of sprays containing α-naphthaleneacetic acid; it was found that water solutions as well as preparations containing Penetrol (an oxidized sulphonated petroleum product used as a carrier for insecticides) were effective.

Pearse and Hwang (1939) carried out a field experiment at East Malling in England in the spring of 1939 in which young apple trees of the variety Cox's Orange were sprayed with various concentrations of α-naphthaleneacetic acid just before and at the time of breaking of the fruit buds. The spray solutions used contained 5 per cent. ethylene glycol and 0·5 per cent. soap with concentrations of α-naphthaleneacetic acid varying from 1 p.p.m. to 800 p.p.m. The results obtained were not favourable, the higher concentrations killed the fruit buds whereas the lower ones were not effective in causing appreciable delay in opening of the buds. Several applications of a dilute spray were also unsuccessful, and injecting solutions of the growth substance into the trees also failed to achieve the desired result.

Winklepleck (1939 and 1940) claimed more favourable results with peaches. He stated that spraying trees with a solution containing 125 mg. of α-naphthaleneacetic acid per litre, at the time when the fruit buds were just beginning to break, resulted in flowering being successfully delayed by at least eleven days.

In general, however, the use of spray solutions of α-naphthaleneacetic acid just before bud break appears to give too variable results, and the danger of damage is too great for the procedure to be of much practical value. It is possible that other more effective chemicals and new methods may yet be found.

Hitchcock and Zimmerman (1943) however, considered that growth substance sprays applied much earlier in the summer would retard the opening of the fruit buds in the following spring. For example when sprays of potassium α-naphthaleneacetate were applied at concentrations of 200, 400 and 800 mg per litre during July, August and September to apple, cherry, peach, pear and plum trees, the delay in opening of the buds the following spring varied from a few days up to 14 days for flower buds and up to 19 days for leaf buds, depending on the time of application and on the concentration of the solution used. For the cherry maximum delay was obtained when the trees were sprayed in August.

Swarbrick (1944a) reported that treating both " cut back " and unpruned one-year-old shoots of large vigorous Crawley apple trees in mid-April with 1 per cent. α-naphthaleneacetic acid or 1 per cent. β-naphthoxyacetic acid either in methylated spirits or in lanolin resulted in greatly delayed or even completely inhibited shoot growth.

Hitchcock (1945) also noted that attempts to retard the development of fruit buds by applying growth substance sprays in spring after the dormant period is over and the buds are beginning their activity is generally unsatisfactory. He considered, however, that if the same sprays are applied in later summer a delay of from one or two weeks in the opening of the flower buds the following spring can be achieved without causing injury to the buds, if care is taken. The exact time of application and the concentrations to use with different varieties have still to be worked out. He stated that in addition to α-naphthaleneacetic acid such substances as 2,4,5-trichlorophenoxyacetic acid and 2,4-dichlorophenoxyacetic acid have also proved effective in low concentrations in limited tests. With the Montmorency cherry a 0·02 per cent. spray of potassium naphthaleneacetate was effective when applied in late July, but a month later 0·04 per cent. and two months later 0·08 per cent. solutions were required to give the same amount of retardation in the opening of the fruit buds the following spring. The same treatments were also effective on apple, but were definitely too damaging for peach and plum trees when applied in July and August. Hitchcock states, however, that these treatments are not yet worked out to a stage where they can be recommended for use on a large scale. He points out that if the treatments are applied too early, or if too high a concentration of spray solution is used, severe damage such as killing of twigs and damage to fruit and leaf buds may result. A further complication is that temperature and environmental conditions in the orchard can play a big part in determining the response obtained, and therefore in every case preliminary experiments should be carried out on a small scale.

Marth, Havis and Batyer (1947) obtained little success in attempting to retard the opening of fruit buds in Elberta peach trees. Sprays containing the potassium salt of α-naphthaleneacetic acid were applied to the trees during August, September and October, and the maximum delay in opening of flower buds the following spring was only two days ; moreover considerable damage to leaves, leaf buds and flowers often occurred. No practical recommendations could therefore be made.

B. Delaying the opening of buds of tung trees.

Sell, Reuther, Fisher and Lagasse (1942) attempted to prolong the dormancy of the buds of tung trees with the object of escaping damage caused by late frosts to developing buds. In preliminary tests the application of α-naphthaleneacetamide contained in a lanolin emulsion to the surface of the buds appeared promising. Direct injection of growth substance into the bud scale sheath was also tried but was not effective. In a second paper Sell, Taylor and Potter (1944) reported that the dormancy of tung tree buds was prolonged by about 12 days by applying a lanolin emulsion without growth substances but that about 7·5 per cent. of the buds were killed by the treatment. When growth substances were added to the lanolin emulsion its effectiveness in delaying bud break was increased, but unfortunately a still higher percentage of the buds was killed. The most favourable treatment was the use of two applications of a 0·25 per cent. solution of α-naphthaleneacetamide in a lanolin emulsion. The first application was made 30 days before and the second 15 days before the normal time of bud swelling. Considerable injury occurred, however, whenever blossoming was appreciably delayed and the treatment caused the death of numbers of the buds. For this reason, no combination or concentration of solution or time of application had yet been found practical for use in commercial orchards.

C. Delaying shoot development of nursery trees during storage.

1. Rose Bushes.

Marth (1942) stated that nursery rose bushes which are dug up and stored for the winter in ordinary storage in the United States are very prone to start into premature growth while still in storage ; this is a distinct disadvantage for transport purposes and for transplanting. He therefore examined the possibility of using growth substance treatments to delay this undesirable shoot growth. Large scale trials were carried out using several different growth substances. The three most effective substances were found to be naphthalene methylacetate, naphthalene ethylacetate and naphthaleneacetonitrile. Applied as wax emulsion sprays at concentrations ranging from 0·01 per cent. to 0·25 per cent. to the shoots of the dormant plants, or as vapours at the rate of from 0·3 to 0·4 g. per 1,000 cubic feet of storage space, growth was successfully inhibited for from 40 to 60 days. Applying the vapour of naphthalene methyl acetate at the rate of 0·3 g. per 1,000 cubic feet of storage space at 32° F. for 16 hours, at 40° F. for four hours or at 70° F. for 1 hour, gave equally effective results. If more than 0·5 g. of the chemical was vaporized per 1,000 cubic feet injury was caused to the shoots, while with amounts lower than 0·1 g. per 1,000 cubic feet shoot growth was somewhat stimulated. It was found that for best results the plants should be placed near the source of the vapour, as the vapour was apt to condense rather quickly.

The treatment resulted in a less rapid depletion of carbohydrate reserves in the plants and this was thought to be partly due to direct inhibition of hydrolysis as well as the slowing down of metabolism by the prevention of shoot growth.

The treatment was most effective on fully mature bushes ; all varieties did not respond equally well, however, and in general it was found that the more difficult a variety was to store without treatment the less satisfactory was the response to treatment with the growth substances. As a result of the conservation of carbohydrate reserves following treatment it was claimed that the bushes made better shoot and root growth and produced more and better blooms when finally planted in their permanent quarters.

2. Other Nursery Trees.

Marth (1942) claimed that treatments similar to those described above for rose bushes were also effective for inhibiting the growth of vegetative buds of apple, peach, pear, cherry, mock orange, Japanese maple and persimmon nursery trees in storage.

Ostrom (1945) working with forest tree seedlings also largely confirmed the results obtained by Marth for rose bushes. Working with seedlings of white ash, vapour and also solution treatments were applied. For the vapour treatment, either 0·3 to 0·5 mg. of naphthalene methylacetate or 0·5 mg. of a mixture of equal parts of α-naphthaleneacetic acid, naphthaleneacetamide, β-naphthoxyacetic acid and indolylbutyric acid was used. For the spray treatment solutions containing either 100 mg. of the acetate per litre or 100 mg. of the mixture per litre gave good results. The use of solutions containing as much as 600 mg. per litre as sprays usually resulted in the death of the plants. These treatments at suitable concentrations were successful in preventing the development of etiolated shoots when the seedlings were kept in common storage, and the inhibition of shoot growth was usually accompanied by a considerable initiation of new roots. The treatments had much less effect on trees heeled-in in the open, however, than on similar batches stored in a shed. The procedure was especially useful when the trees were planted out late (June), and in such cases resulted in better survival and better root growth : when trees were planted out earlier in the season differences in favour of treatment were much less distinct.

The pre-storage growth substance treatments also resulted in a higher percentage survival on planting out of trees that were kept in cold storage at 32° F., but untreated trees kept in cold storage were better than those treated with growth substances and stored at ordinary temperatures.

Similar pre-storage treatments with growth substances did not, however, improve the percentage survival of loblolly or short-leaved pine seedlings. An application of a plain lanolin emulsion containing 50 g. per litre to the dormant shoots of short-leaf pine, pitch pine and tulip tree seedlings before storage was, however, usually successful and resulted in a higher percentage survival of the trees both during storage and after planting.

Way and Maki (1946) treated black locust and loblolly pine seedlings with medium and relatively high concentrations of α-naphthaleneacetic acid (a) in a closed chamber by the vapour method, (b) by the aerosol method and (c) by dipping in a lanolin emulsion containing the growth substance. Eastern red oak and red pine seedlings were also treated using the emulsion dip method. After treatment the seedlings were stored from 5 to 10 weeks and then planted out in the field.

The pines were much more sensitive to treatment with the growth substance and much more liable to injury than the hardwood seedlings. With suitable concentrations the period over which the seedlings could be kept in common storage was somewhat increased, but the results obtained were considered to offer no promise of the replacement of cold storage by growth substance treatments when a long storage period was required.

OTHER PRACTICAL USES OF GROWTH SUBSTANCES

I. CONTROL OF FLOWERING IN THE PINEAPPLE

Attempts to control flowering and the initiation of floral primordia, by the external application of any of the well-known growth regulating substances, have in most cases failed entirely. The outstanding exception, however, has been in the case of the pineapple.

Clark and Kerns (1942) as the result of experiments carried out in Hawaii considered that by the application of appropriate concentrations of growth substances such as α-naphthaleneacetic acid, α-naphthaleneacetamide, and naphthalene-thio-acetamide flowering in the pineapple could be either induced considerably in advance of the normal flowering period, or delayed until much later. Cooper (1942) working in Florida obtained slightly different results. He found that treatment with α-naphthaleneacetic acid accelerated flowering when applied in October, but not if applied during July, August or September. Treatment with ethylene on the contrary induced flowering equally well in summer and in autumn. The difference in the results obtained with growth substance treatment was thought to be quite probably due to differences in climatic and environmental conditions. Van Overbeek (1945 and 1946) made a further detailed study of the problem and was successful in his experiments in controlling flowering throughout the year. The treatment used consisted of the simple expedient of pouring 50 ml. of a growth substance solution of appropriate concentration into the centre of the plant from a small beaker. The beaker could also be used as a measure when large numbers of plants were to be treated. Amounts of α-naphthaleneacetic acid or its salts as low as 0·05 mg. per plant were capable of inducing flowering in some plants, whilst amounts of 0·25 mg. and 0·5 mg. per plant caused almost 100 per cent. of the treated plants to flower. It was also possible to use 2,4-dichlorophenoxyacetic acid as the active chemical, but the fruits produced when this substance was used were usually smaller and weighed less than when α-naphthaleneacetic acid was used. The weight of the fruit produced also depended on the size of the plant when treated. Van Overbeek considered that, employing this treatment with α-naphthaleneacetic acid, fruit production in pineapples should be possible at any time of the year, provided plants of the requisite size were available for treatment. Under the conditions of his experiments plants having sixteen or twenty leaves when treated produced fruit weighing about 2 kilogrammes, but if 21 to 31 leaves were present fruit weighing about 3 kilogrammes were obtained. By suitable adjustment of size of plant and time of treatment, therefore, both the weight of the fruit and the time of production of the fruit could be controlled throughout the year. These experiments were carried out using the Cabezona variety of pineapple.

II. THE EFFECT OF GROWTH SUBSTANCES ON THE OPENING OF FLOWERS

Mitchell and Cullinan (1942a) attempted to influence the rate of opening of floral buds of peaches and pear by growth substance treatments. Lanolin and oil emulsions containing different amounts of indolylacetic acid, indolylbutyric acid, naphthaleneacetic acid or naphthaleneacetamide were sprayed on to detached branches kept under controlled conditions in a greenhouse. Floral buds on detached branches of both Elberta and Belle peach varieties, opened sooner and in much greater numbers when treated at an early stage of swelling, with emulsions containing α-naphthaleneacetic acid, than when sprayed with the emulsion alone. Naphthaleneacetamide applied in a similar manner was much more effective in accelerating flowering in the Belle variety than in the Elberta variety. When the emulsions containing the growth substances were applied after the buds were fully swollen but with the petals not yet open very little response was obtained. Single applications of indolylacetic acid or indolylbutyric acid were practically without effect, but repeated applications of indolylacetic acid, made as the buds were swelling, significantly increased the rate at which blossoms of the Belle variety opened.

None of the compounds tested accelerated the opening of floral buds of pear and repeated treatments with relatively high concentrations only resulted in damage to the buds.

Van Stuivenberg (1946b) stated that the opening of rose buds could be accelerated by treatment with growth substances. Standing cut roses (Better Times) in solutions of potassium α-naphthaleneacetate (1 g. per litre) resulted in quicker and more even opening. Cumarine and extracts from beet seeds also exerted influences in the same direction.

Control of flower opening by the aid of growth substances has not yet reached a stage at which practical recommendations can be made, and attempts to prolong the life of cut flowers by their use has also not met with much success thus far.

III. ATTEMPTS TO INFLUENCE FRUIT BUD INITIATION IN DECIDUOUS FRUITS

Magness, Batjer and Baynes (1943) bearing in mind the well-known mobilizing effect of growth substances on carbohydrate constituents, and the possibility that large amounts of carbohydrates in the stems may lead to fruit bud formation, attempted to influence fruit bud formation in apples by applying growth substance preparations. Using emulsions in lanolin and in oil concentrations of α-naphthaleneacetic acid and α-naphthaleneacetamide, from 20 p.p.m. to 50 p.p.m. were applied. Fruit bud formation was not increased with any of the treatments used.

IV. USE OF GROWTH SUBSTANCES IN GRAFTING AND WOUND HEALING

A. Grape vines.

Kordes (1938) immersed stocks and scions of grapes for 16 hours in a 0·01 per cent. water solution of indolylacetic acid. After completing grafting operations the grafts were stored for a period in moist sawdust before planting out in the field. The treatment was said to be both effective in increasing root formation in the stock and the rate of callusing of the graft union. Müller-Stoll (1938) also described experiments on the effect of synthetic indolylacetic acid in aqueous solution on the " taking " of grafts of grape vines. Four different concentrations containing respectively 0·1, 0·067, 0·05 and 0·025 per cent. of the active compound were tested for their effect on callus formation. Three different methods of application were used, namely, (1) immersion in solutions, (2) painting the surfaces and (3) spraying. Considerable stimulation of callus formation was obtained and the most satisfactory results were with the 0·05 per cent. concentration. Lanolin pastes containing indolylacetic acid were also tried but gave inferior results. In another paper Müller-Stoll (1940) described further investigations on the effects of solutions of indolylacetic acid on vine grafts. It was found that a considerable increase in speed of " taking " could be obtained by spraying the bundled grafts with a solution of indolylacetic acid or by a short immersion of the cut surfaces of both graft partners in a solution, before they were combined. Phenylacetic acid also gave some response, but the addition of saponin or adhesive pastes to the growth substance solutions was injurious.

Immersion of the ends of both the stock and the scion in a dilute solution of indolylacetic acid for 16 to 20 hours before grafting was one of the best methods. If the humidity was too high in packing the completed grafts, root formation was undesirably stimulated, but this could be avoided to a large extent by using drier conditions. The advantage of the treatment was that it caused a strong, even ring of callus tissue to form at the junction of the graft. Lefèvre (1939) also reported favourably on the use of indolylacetic acid and indolylbutyric acid in vine grafting.

Anliker and Kobel (1945), however, did not report so favourably. They carried out a number of experiments and could obtain neither conclusive nor consistent results. They therefore concluded that the general use of growth substances in grafting grape vines could not be recommended.

B. Deciduous fruits.

Evenari and Konis (1938) reported beneficial results by the use of growth substances on apple grafts but not on those of cherry or pear. They also called attention to an undesirable effect of the treatment when the growth substances were applied directly to the graft union, in that such treatment often caused excessive callusing and proliferation which tended to push stock and scion apart.

Kawakami and Isimaru (1941) found that treatments with indolylacetic acid or as a lanolin paste containing 0·1 per cent. were useful in budding plums. The lanolin paste method was more satisfactory than the use of aqueous solutions but was liable to result in injury in some cases.

Lanolin pastes containing indolylacetic acid were without benefit for the spring grafting of plums. Other solvents for the growth substance, such as lard and turpentine, proved inferior to lanolin perhaps because of their lower melting points.

C. Nut trees.

Lounsberry (1938) reported the results of some experiments with root grafts. A paste containing 1 gramme of either indolylacetic acid or indolylbutyric acid per 200 grammes of lanolin was spread thinly on the top of the scion and around the union of the graft and at the lower end of the seedling root where it was cut off. This treatment caused plentiful root production from the lower end of the scion as well as on the seedling root, with several varieties of English walnut, Japanese butternut, pecan and shagsbark hickory. Similar results were also obtained by immersing the scions for 24 hours to a depth of 1 inch in a solution containing 20 p.p.m. indolylbutyric acid. With the black walnut, using similar treatment, no roots came from the scions, but roots were formed from both the apical and basal portions of the seedling root used as stock.

D. Rhododendron.

Kruyt (1944a) stated that immersion of the scions immediately before grafting in a solution of ethylene chlorohydrin in warm water, or warm water containing growth substance induced better callus formation and also speeded up bud development. It was thought that the warm water treatment alone, being a simple technique which by itself encouraged early union of the graft and hastened bud development in the scion, would be of considerable practical use.

E. Healing of wounds.

Shear (1936) treated pruning cuts of apple, maple and linden with a lanolin paste containing 0·5 per cent. of indolylacetic acid and with pure lanolin. The lanolin used alone stimulated callus formation slightly and the addition of indolylacetic acid did not increase this effect. Jakěs and Hexnerovǎ were more successful and reported that a lanolin paste containing 1 per cent. indolylacetic acid, applied to wounds on the terminal shoots of peach, plum, apple and pear trees, increased the rate of healing. A feature of the response obtained was that the treated wounds produced abundant callus, not only at the edges of the cut bark, but also in independent centres over the entire wound surface.

Oliver and Grace (1940) mention experiments carried out on young Green Ash trees (*Fraxinus pennsylvanica lanceolata*). Bark wounds were made in the autumn and in the spring, and the cambium layer was then painted with linseed oil pastes containing powdered indolylbutyric acid, at rates of from 500 to 3,000 p.p.m. Some early stimulation of callus formation was observed in the wounds treated in the spring, but later this advantage over untreated control wounds tended to disappear.

V. USE OF GROWTH SUBSTANCES IN PREVENTING ABSCISSION OF PLANT PARTS

One of the earliest known effects of plant growth substances was that of delaying the abscission of petioles of leaves after the leaf blade had been removed. From this observation followed one of the most useful and economically important aspects of the use growth substances in practical horticulture, namely the control of the pre-harvest drop of fruit such as apples and pears. This subject has recently been very thoroughly and clearly reviewed by Vyvyan (1946) in *Technical Communication No. 18* of the Imperial Bureau of Horticulture and Plantation Crops, and for full information the reader is therefore referred to that publication.

There are one of two other cases where the action of growth substances in delaying abscission are useful in practice, however, and these are very briefly mentioned here.

A. Prevention of defoliation in cut holly.

Milbrath and Hartman (1940) sprayed cut branches of holly (*Ilex aquifolium*) with solutions of α-naphthaleneacetic acid; control branches were similarly sprayed with water alone. Despite the fact that the branches were standing in water, control branches defoliated completely within 48 hours of gathering, when exposed to low concentrations of ethylene gas. Branches which had been sprayed with a 0·005 per cent. solution of α-naphthaleneacetic acid, however, kept their leaves for many days, in fact, up to time when the leaves began to die and turn black.

Milbrath and Hartman (1941) carried out further investigations and fully confirmed the fact that solutions of α-naphthaleneacetic acid or α-naphthaleneacetamide applied as a spray to cut holly branches prevented the branches losing leaves for long periods, even when the holly was packed wet or exposed to ethylene gas (a well-known defoliating agent). Well-known commercial preparations containing α-naphthaleneacetic acid or its salts and sold for prevention of pre-harvest drop of fruit were also quite effective, but it was recommended that they should be used at twice the strength normally used as a pre-harvest drop spray.

A very convenient method of application, too, consisted in simply dipping or submerging the cut branches momentarily in the growth substance solution and then allowing surplus liquid to drain off immediately. The same dipping solution remained effective for several days and no objectionable deposit was left on the leaves, which might spoil their utility for decorative purposes. The same solution was also effective in preventing drop of berries from the cut branches.

When an oil emulsion had to be used to kill scale or other insect pests on the branches it was found best to apply this first and give the growth substance dip afterwards. Milbrath and Hartman (1942) also studied the effect of temperature on the defoliation of cut holly branches. It was found that holly packed wet and stored in the presence of small concentrations of ethylene gas did not lose its leaves in 30 days when the temperature was held at 31° F. At 36° F., 25 per cent. of the leaves were lost after two weeks storage and at 42° F. defoliation was complete in the same time. When the cut branches were kept under similar conditions but with no ethylene gas present, no defoliation occurred either at a temperature of 31° F. or at 36° F., but at a temperature of 46° F. the branches started to lose leaves after 2 weeks. When the holly was stored wet in an open building, where the temperatures fluctuated from 20° F. to 60° F. but were mostly in the lower part of this range, the branches kept fresh and the leaves bright and shiny even up to 40 days or more.

Allowing the branches to dry out partially after cutting also delayed the loss of leaves considerably, apparently retarding the development of the abscission layer in the petioles.

At higher temperatures, dipping the cut branches in solutions of α-naphthaleneacetic acid was again found very useful in preventing leaf drop. Thus, dipping in a 0·01 per cent. solution of the acid entirely prevented leaf drop for a 14 day period at temperatures from 70° F. to 80° F. whereas comparable control branches dipped in water lost all their leaves within 3 days under similar conditions. Even the use of a solution as dilute as 0·001 per cent. had a considerable delaying effect on defoliation. No injury occurred except when very high concentrations of the growth substance were used and no unsightly deposits were left on the leaves. When holly branches were treated with α-naphthaleneacetic acid and the holly was subsequently packed near apples (which give off ethylene) there was some defoliation, and therefore in the storage and transport of holly branches it was suggested that care should be taken to keep it away from fruit or other possible sources of ethylene.

B. Controlling defoliation in cut branches of other evergreens.

Clair, Worley and Grogan (1941) found that defoliation of cut branches of *Euonymus* could be delayed 11 days by a suitable treatment with a solution of α-naphthaleneacetic acid, and even more striking results were obtained with American holly (*Ilex opaca* Ait). The treatment was, however, of no value for Live Oak (*Quercus virginiana* Mill.) or for magnolia (*Magnolia grandiflora* L.). Results with pine (*Pinus strobus* L.) were erratic. Carolus, Lee and Vandemark (1947) also found the methyl ester of α-naphthaleneacetic acid useful in preventing abscission of leaves of cauliflowers kept in cold storage.

C. Preventing the dropping of buds and flowers in lupins, and other flowers.

Warne (1947) stated that preliminary experiments carried out by him in 1937 had shown that the tendency of many garden varieties of lupins to shed both flower buds and flowers, both while still attached to the plant and after cutting, could be prevented to a considerable degree by suitable applications of growth substances. In these early experiments it was found, for example, that inflorescences sprayed, when the buds were just beginning to show colour, with a solution of either α-naphthaleneacetic acid or indolylacetic acid at a concentration of 0·05 per cent., retained their buds and flowers well, whereas control series sprayed with water alone shed nearly all their buds and flowers after nine days. In the later work Warne (1947) carried out more extensive experiments. In a series of trials with Russell lupins, the inflorescences were cut at noon and treated with growth substance solutions about 5 hours later. The treatment consisted in spraying the inflorescences with aqueous solutions of the growth substances, and at the time of application the lowest buds on the spike were usually fully open. Both indolylacetic acid and α-naphthaleneacetic acid used at concentrations of from 0·04 per cent. to 0·08 per cent. had a considerable effect in preventing bud and flower drop. Typical results were: Var. Lady Miles Mitchell treated with indolylacetic acid at 0·04 per cent. shed only an average of 19 buds and flowers per inflorescence in 69 hours as compared with 137 for control ones; the Maud Tippetts variety shed only 12 buds and flowers per inflorescence in 69 hours when treated with α-naphthaleneacetic acid, but controls lost 134 in the same time. Further work is necessary to discover under what precise conditions the treatments are likely to be most effective, but Warne considers that the method holds out the hope of increasing the value of the lupin as a cut flower.

Lodder (1946) successfully used sprays of potassium naphthaleneacetate to reduce bud and flower fall in begonias.

D. Use of ethylene to encourage abscission.

It may be mentioned here that the effect of ethylene in hastening the abscission of plant organs, as noted above for holly leaves in the work of Milbrath and Hartman (1942), may also be of practical use in certain cases. Thus Arrillaga and Jones (1944) required some quick means of causing the abscission of plant parts from which essential oils and other compounds were to be extracted, in order to facilitate the harvesting of the required material. They found that ethylene could be used to induce the abscission of the flowers of ilang-ilang (*Canangium odoratum*) and chinabox jasmine orange (*Murraya exotica*). Acetylene and carbon monoxide were also tried but were ineffective for flowers of ilang-ilang.

E. Possible use of growth substances for counteracting defoliation caused by oil sprays on citrus trees.

Oil emulsion sprays are an effective method of combating many of the insects attacking citrus trees, but unfortunately their use is often limited by the fact they are prone to cause a considerable amount of leaf and fruit drop under some conditions. Preliminary experiments carried out by Stewart and Ebeling (1946) gave some promise that it might be possible to overcome this disadvantage, at least to a considerable measure, by the addition of growth substances such as 2,4-dichlorophenoxyacetic acid to the oil sprays. In small scale field trials, it was found that the addition of from 0·025 per cent. to 0·05 per cent. of 2,4-dichlorophenoxyacetic acid to the oil in oil emulsion sprays used on orange trees reduced the amount of leaf drop caused by them from 26 to 57 per cent. The effectiveness of this procedure in reducing leaf drop depended to a considerable extent on the properties of the oil and on the amount of the growth substance which was added. Drop of fruit caused by oil spraying was also considerably reduced. Unfortunately the phenoxy acid was liable to cause injury to the tree and to retard its growth, and this, of course, was a serious drawback. If the sprays were applied when the trees were not in active growth the amount of injury caused was least ; but if applied during a growth flush considerable damage was often caused. Owing to this tendency to damage, the use of 2,4-dichlorophenoxyacetic acid as a spray oil addition could not as yet be recommended for commercial practice without further investigation, but it was hoped that with adjustments or perhaps the use of other growth substances that this disadvantage would be overcome. Cole and Heeley (1947) also found that a white oil emulsion at a strength of 1 per cent. could be safely used on apple trees (Cox's Orange Pippin) while in leaf, for the control of red spider, provided it contained 10 p.p.m. of α-naphthaleneacetic acid. When used without the growth substance serious drop of leaves and fruits was caused by the oil spray.

VI. THE POSSIBLE USE OF GROWTH SUBSTANCES IN THE TREATMENT OF FRUIT IN STORE

A. Effect on rate of ripening.

Traub (1938) observed that treating unripe fruits with weak solutions of plant growth substances increased their storage life, but that the use of stronger solutions decreased it.

Fruits of *Passiflora edulis*, *P. antiguensis*, tree tomato (*Cyphomandra betacea*), grapefruit (*Citrus grandis*), sweet orange (*C. sinensis*), lemon (*C. limonia*) and lime (*C. aurantifolia*) were treated with watery solutions of indolylacetic acid, indolylbutyric acid, and α-naphthaleneacetic acid or with 1 per cent. lanolin pastes of these substances. The fruits which were half submerged in a peat and sand mixture, were treated at the stem or calyx ends with lanolin pastes, or were soaked in growth substance solutions. Alternatively the entire fruits were immersed in solutions of various concentrations for 24 hours or were completely covered with a very thin film of lanolin paste containing the growth substance. The solutions of higher concentration, 0·05 per cent., accelerated, whereas the more dilute ones, 0·01 to 0·001 per cent. arrested senescence, in all the types of fruit studied.

Reyneke and Pearse (1945), in studying the effect of dipping in various oil emulsions on the respiration rate of pears (Bon Chrétien), found that indolylacetic acid added to the emulsion in low concentrations slightly increased the rate of respiration, but that high concentrations reduced it.

Gerhardt and Allmendinger (1945) found that the ripening of pears, treated with α-naphthaleneacetic acid on the tree to control pre-harvest drop, was sometimes slightly accelerated, especially if picking was delayed. Batjer and Moon (1945) also concluded that the same substance, used as a pre-harvest drop spray, stimulated the ripening of early varieties of apples such as Close, Williams and Duchess of Oldenburg. Haller, Batjer and Moon (1945) concluded that with later varieties such as Delicious, Jonathan and Rome Beauty, the growth substance spray did not affect ripening or storage quality, provided the fruit was picked at the correct stage of maturity.

Van Stuivenberg (1946a), however, treated detached fruits of Sterappel by dipping them in solutions of α-naphthaleneacetic acid, at concentrations ranging from 10 to 200 mg. per litre. It was found that when the higher concentrations were employed ripening was definitely hastened. Certain varieties of pears also ripened more quickly when dipped in α-naphthaleneacetic acid solution (200 mg. per litre) after picking. When the fruit was stored at 20° C. the effect was greatest on early picked fruits ; fruits picked at a more mature stage ripened so quickly without treatment that no difference, due to treatment with the growth substance, was noticed. When the pears were cold stored at 1° C. after treatment, the magnitude of the response also varied with the stage at which the fruit were picked.

Mitchell and Marth (1944) observed the effects of 2,4-dichlorophenoxyacetic acid treatment on the subsequent ripening of detached fruits and vegetables. It was found that when the chemical was applied, either in aqueous solution containing some Carbowax or as aerosol, the ripening of bananas, apples and pears was hastened. The treatment appeared to have little effect, however, on the ripening fruits such as tomato, persimmon and pepper which have little or no starch reserves.

In all cases, the fruits were collected while still green and sprayed with or dipped into, water solutions of 2,4-dichlorophenoxyacetic acid solution, at strengths of 100, 250, 500, 800, 1,000 and 1,600 p.p.m. and containing, in addition, from 0·5 per cent. to 2·0 per cent. Carbowax 1,500. The aerosol mixtures when used, were composed of 94 per cent. dimethyl ether, 5 per cent. cyclohexanone, and 1 per cent. of dichlorophenoxyacetic acid. The ripening of bananas was hastened by from 3 to 8 days by treatment, and Yellow Newtown apples ripened in two weeks, whereas untreated controls were still hard and green after the same period. Grimes Golden apples picked 1 week previous to the normal picking date, were ripened in 6 days whereas untreated ones took 2 weeks; Rome Beauty apples ripened 2 to 6 days earlier; Kieffer pears ripened 2 to 4 days more quickly, and Winter Bartlett pears ripened in 8 to 10 days following treatment, in which time untreated fruit was still unripe.

The treatment also had the advantage of causing very even ripening in a batch of fruit; a very important point, as even ripening adds very greatly to the appearance and attractiveness of a box of fruit.

As a result of the treatment of bananas it was found that starch hydrolysis proceeded at a much more rapid rate; this was determined both by taste and iodine tests. The fact that the main effect of the growth substance was to speed up starch hydrolysis was thought to explain why the treatment had little effect on non-starch-containing fruits such as tomato, pepper and persimmon. With these fruits colour changes during ripening were not hastened by the treatment.

Southwick (1946) also found that submerging peaches for from 5 to 10 seconds in solutions of 2, 4-dichlorophenoxyacetic acid at concentrations of 500 to 1,000 p.p.m. and containing 0·5 per cent. Carbowax greatly increased the rate of softening. Treatment with preparations containing the methyl or the ethyl ester of α-naphthaleneacetic acid also had a considerable effect in the same direction. Application of a talc dust containing 3 per cent. of methyl-α-naphthaleneacetate to bearing peach trees also considerably hastened ripening of the fruit, but unfortunately this treatment resulted in serious foliage injury and the quality of the fruit was inferior. For detached fruits two commercial preparations Stor-Aid No. 1 which consists of 3 per cent. methyl-α-naphthaleneacetate and 97 per cent. confetti and Stor-Aid No. 2 composed of 2 per cent. methyl-α-naphthaleneacetate and 98 per cent. talc were also effective for accelerating ripening, when distributed among the fruits.

Smock and Gross (1947) found that under some conditions pre-harvest drop sprays of α-naphthaleneacetic acid stimulated respiration rate and rate of ripening of apples. The effect was especially noticeable in apples kept at high temperatures (74° F.) after picking. Dip treatments also stimulated respiration.

B. Effect on apple scald.

Schomer and Marth (1945) treated apples of the Arkansas, Staymans Winesap, Grimes Golden and York Imperial varieties, after harvesting, with solutions of α-naphthaleneacetic acid and indolylbutyric acid or with a mixture of equal parts of these two acids with α-naphthaleneacetamide and β-naphthoxyacetic acid. The solutions were applied either by spraying or by dipping the fruit in them and the fruit was then stored at 31° F. After a period of cold storage, the fruits were removed to a temperature of 70° F., and examined for scald after 7 days at this temperature. The treatments resulted in a considerable reduction in the amount of scald appearing, the greatest response being in those of the Arkansas variety; in them scald was reduced by 24 per cent. There were no appreciable differences in response according to the particular growth substances used, and the actual concentration used, namely 10, 100, and 500 p.p.m., seemed to be more or less unimportant. The dipping method of treatment did, however, give slightly better control of scald than either the spraying method or the aerosol method of application, also tested.

VII. POSSIBLE USE OF GROWTH SUBSTANCES FOR BLOSSOM THINNING OF FRUIT TREES

Schneider and Enzie (1943 and 1944) investigated the possibility of using growth substance sprays, applied at the stage of full bloom, to influence the set of apples. Solution sprays of indolylbutyric acid, indolylacetic acid, or indolylpropionic acid applied during an " off " year did not, however, have any appreciable effect on the set during the year of application, with either the Stayman's Winesap or the Arkansas Black varieties.

It was found, nevertheless, that α-naphthaleneacetic acid showed considerable promise as a substance for reducing fruit set. When applied during the " off " year at concentrations of 0·01 per cent. or 0·03 per cent. it almost entirely eliminated set : unfortunately the spray caused a good deal of injury to the leaves. The number of flower buds formed during the following " on " year was also reduced, however, so that it was considered that the spray might be of practical use as an " off " year spray to reduce flower bud formation for the " on " year. When used at lower concentrations (0·003 per cent.) the spray considerably reduced set without causing foliage injury, and if a wetting agent was included still lower concentrations such as 0·002 per cent. or even 0·001 per cent. were effective in achieving the same result. Sprays of α-naphthaleneacetamide (0·008 per cent.) applied at full bloom during the " on " year also reduced set considerably without causing any visible injury to the trees.

Davidson, Hamner, Reimer and Dutton (1945) also found that sprays of sodium α-naphthaleneacetate could be used to produce marked thinning of the fruit of several varieties of apple. The greatest thinning, sometimes too severe in fact, occurred when the spray was applied at full bloom. Applications made just before or just after full bloom, were less effective, but often resulted in the desired amount of thinning. The response and amount of thinning achieved varied greatly with different varieties, and a further complication was the fact that a single variety did not react to the same extent each season. The spray could be used alone, or included with fungicidal and insecticidal sprays such as wettable sulphur, hydrated lime and lead arsenate. The foliage of the trees was not injured to any appreciable extent ; but the results were considered too variable for any definite recommendations to be made for large scale application at this stage.

Stebbins, Neal and Gardner (1946) investigated the use of App-L-Set (a commercial preparation containing the sodium salt of α-naphthaleneacetic acid), both alone and in combination with an oil wax emulsion, as a bloom thinning agent for apples. When applied at a concentration of 10 p.p.m., moderate bloom thinning was obtained using the Wealthy variety of apple. Some dwarfing and curling of the foliage was noticed, but this undesirable response was considerably reduced when an oil-wax emulsion, at a dilution of 1 in 400 was added to the spray. When the spray was applied at a concentration of 20 p.p.m., thinning was too severe with the Wealthy and McIntosh varieties ; in fact McIntosh blooms were so sensitive that an over-thinning resulted even with the 10 p.p.m. spray. Typical results obtained were as follows ; App-L-set alone at 10 p.p.m., 54 per cent. thinning, with the Wealthy variety when applied at full bloom, and 40 per cent. when applied at early petal fall ; with the McIntosh variety, 73 per cent. thinning when applied at petal fall and with the Duchess variety 26 per cent. thinning when applied as a calyx spray. When an oil-wax emulsion was added to the spray the corresponding results for the same varieties were 48 per cent., 45 per cent., 94 per cent. and 42 per cent. thinning.

In this work, also, the importance of the variety was stressed ; thus the blooms of the McIntosh variety were excessively thinned by an application made at petal fall, whereas the same spray applied at full bloom to the trees of the Wealthy variety achieved just about the amount of thinning desired. It is, therefore, important that for each variety in each particular environment, small scale tests should be made before embarking on large scale applications.

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES

Abbreviations :

IAA indolylacetic acid.
IBA indolylbutyric acid.
IPA indolylpropionic acid.
NAA alpha naphthaleneacetic acid.
* Estimated percentages.
NAD alpha naphthalene acetamide.
p.p.m. parts per million.

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Abelia chinensis R.Br.	Abelia	Metcalfe and Templeman 1939	Sept.	IAA or IBA 50 p.p.m. 17 to 24 hrs.	3	—	—	Percentage rooting and number of roots increased
A. grandiflora Rehd.		Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
do.		Yerkes 1938	Jan.	IBA 50 p.p.m. 21 hrs.	5	93	33	
A. rosea alba		Kirkpatrick 1939 Kirkpatrick 1939	— —	IBA 10 p.p.m. 24 hrs. or IBA talc dust 2000 p.p.m.	— —	— —	— —	Beneficial
A. schumannii Rehd.		Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 17-24 hrs.	4	—	—	Some benefit
Abeliophyllum distichum Nakai		Metcalfe and Templeman 1939	July	IAA 50 p.p.m. 17-24 hrs.	4	—	—	Beneficial
Abies concolor Lindl. Gord.	White Fir	Maxon, Pickett and Richey 1940	Jan.	IBA 80 p.p.m. 24 hrs. (Hormodin)	9	17*	0*	Beneficial
do.		Thimann and Delisle 1942	March	IAA 160 p.p.m. 24 hrs.	—	68	19	2 per cent. sucrose for 48 hrs. after growth substance

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
A. koreana	Korean Fir	Thimann and Delisle 1942	March	IAA 100 p.p.m. 24 hrs.	—	16	0	
do.		Thimann and Delisle 1942	Jan.	IAA 200 p.p.m. 24 hrs.	—	70	25	
A. pectinata DC.	Silver Fir	Thimann and Delisle 1942	Jan.	IAA 200 p.p.m. 24 hrs.	—	80	4	2 year-old wood
do.		Thimann and Delisle 1942	Jan.	IAA 200 p.p.m. 24 hrs.	—	45	6	Cuttings from mature tree
A pinsapo Boiss.	Spanish Fir	Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA-talc dust 12,000 p.p.m.	—	—	—	Beneficial
A. veitchii Lindl.	Veitch Fir	Kirkpatrick 1940	—	BIA 40 and 80 p.p.m. 24 hrs. or IBA talc dust 12,000 p.p.m.	—	—	—	Beneficial
Acacia alata R.Br.	Winged Acacia	Tincker 1938	July	IAA or NAA 100 p.p.m. 24 hours	—	—	—	No benefit
A. decurrens dealbata Willd.	Silver Green Wattle	Tincker 1938	July	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	No benefit
A. longifolia mucronata Willd.	Sydney Golden Wattle	Tincker 1938	June	NAA 33 p.p.m. 24 hrs.	—	—	—	No benefit
Acalypha hispida Burm. f.	Red-Hot Cat-Tail	Maxon, Pickett and Richey 1940	April	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	42*	7*	Beneficial
A. wilkesiana Muell. var. *marginata* Hort.		Maxon, Pickett and Richey 1940	April	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	—	—	Beneficial

A. wilkesiana Muell. var. *obovata* Hort.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	2	100	100	More roots
A. wilkesiana Muell. var. *hamiltoniana* Hort.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	2	100	100	More roots
Acantholimon glumaceus Boiss.	Prickly thrift	Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit Cuttings died
A. venustum Boiss.		Cox 1937	July	IAA 100 p.p.m. 18 hrs.	5	—	—	No benefit Rooting delayed
Acanthopanax sieboldianum	Acanthopanax	Chadwick 1937	Aug.	IBA 100 p.p.m. 20 hrs.	8	80	50	
Acer campestre L.	Hedge Maple	Chadwick 1937	June	IBA 10-80 p.p.m. 12 hrs.	—	—	—	No benefit
A. palmatum Thunb.	Japanese Maple	Chadwick 1937	June	IBA 50 p.p.m. 20 hrs.	6	20	0	
A. platanoides L.	Norway Maple	Thimann and Delisle 1939	June	IAA 100 p.p.m. 24 hrs.	—	—	—	Some benefit
A. rubrum L.	Red Maple	Snow 1941	June	IBA 20 p.p.m. 6 hrs.	8	63	0	
A. rufinerve Sieb. and Zucc. var. *albo-limbatum* Hook.	Redvein Maple	Tincker 1938	Oct.	NAA 50 p.p.m. 24 hrs.	—	12	0	
A. saccharum Marsh.	Sugar Maple	Scholz 1937	July	IAA 10 p.p.m. 48 hrs.	6	100	0	
do.	do.	Snow 1941	June	IBA 50 p.p.m. 3 hrs.	—	85	0	
Actinidia arguta Miq.	Bower Actinidia	Stoutemyer 1939	June	NAA talc 1,000 p.p.m.	2	88	38	
Actinidia chinensis Planch.	Climbing Actinidia	Schulz 1937	July	IAA 100 p.p.m. 48 hrs.	6	100	60	
Ageratum houstonianum Mill.	Mexican Ageratum	Maxon, Pickett and Richey 1940	Feb.	IBA 10 p.p.m. 24 hrs. (Hormodin)	2	90*	26*	Beneficial

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Aleurites moluccana Willd.	Candlenut	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Allamanda cathartica L.	Common Allamanda	Maxon, Pickett and Richey 1940	Feb.	IBA 20 p.p.m. 24 hrs. (Hormodin)	8	72*	47*	Beneficial
do.	do.	Maxon, Pickett and Richey 1940	Nov.	IBA 20 p.p.m. 24 hrs. (Hormodin)	7	—	—	Very beneficial
Alnus glutinosa Gaertn. var. *aurea* Versch.	Black Alder	Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. glutinosa Gaertn. var. *imperialis* Desf.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. glutinosa Gaertn. var. *laciniata* Willd.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. glutinosa Gaertn. var. *quercifolia* Loud.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. hirsuta Turcz. var. *sibirica* Schneid.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. incana Willd. var. *aurea* Schelle f. *variegata* Hort.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
A. incana Willd. var. *pendula* Callier		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died

Alternanthera amoena Voss		Hubert and Beke 1938	Dec.	IAA 50 p.p.m. 6 hrs.	1	100	100	More roots per cutting
Amorpha sp.	False Indigo	Warner and Went 1939	April	IAA 200 p.p.m. 24 hrs.	5	8	0	Hardwood cuttings
do.		Warner and Went 1939	April	IAA 200 p.p.m. 24 hrs.	5	87	50	Softwood cuttings
Anona cherimola Mill.	Cherimoyer	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Anthyllis barba-jovis L.	Jupiter's Beard	Metcalfe Templeman 1939	July	NAA 50 p.p.m. 17-24 hrs.	—	—	—	More cuttings rooted
A. hermanniae L.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 17-24 hrs.	—	—	—	No benefit All cuttings died
Antirrhinum majus L.	Common Snap-dragon	Maxon, Pickett and Richey 1940	Nov. and March	IBA 10 p.p.m. (Hormodin)	4	95*	47*	More cuttings rooted
Araucaria brasiliana A. Rich.	Araucaria	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Arbutus unedo L.	Strawberry Tree	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
do. " New Scarlet "	do.	Cox 1937	Feb. April	IAA 100 p.p.m. 24 hrs.	—	—	—	Considerable benefit
Arctostaphylos manzanita Parry	Common Manzanita	Metcalfe and Templeman 1939	July	IAA, NAA and IBA 50 p.p.m. 24 hrs.	—	—	—	No benefit All cuttings died
do.		Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
A. uva-ursi Spreng.	Bearberry	Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
do.		De France 1939	Feb.	IBA 20-40 p.p.m. 24 hrs.	—	—	—	Considerable success with terminal and lateral cuttings.

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Aristolochia macrophylla Lam.	Dutchman's Pipe	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	40	0	
Aronia arbutifolia Spach	Red Chokeberry	Yerkes 1938	July	IBA 10-80 p.p.m. 10 hrs.	—	—	—	No benefit
Atraphaxis muschketowii Krassn.	Atraphaxis	Metcalfe and Templeman 1939	June	IAA, IBA and NAA 20 p.p.m. 24 hrs.	—	—	—	No benefit
Aucuba japonica Thunb	Aucuba	Hubert and Beke 1938	Jan.	IAA 50 p.p.m. 8 hrs.	7	90	50	
Azalea arborescens Pursh.	Azalea	Yerkes 1938	June	IBA 80 to 100 p.p.m. 4 hrs.	9	60	70	Wood in active growth. Deciduous azaleas withstood somewhat stronger concentrations without injury than Kurume varieties
do.		Kirkpatrick 1939	July	IBA talc 5,000 p.p.m.	6	100	0	
do. var. *grandiflorum*		Kirkpatrick 1939	June	IBA talc 12,000 p.p.m.	5	75	25	
A. calendulacea Michx.		Yerkes 1938	June	IBA 50 to 100 p.p.m. 22 hrs.	10	40	0	Taken while in active growth. No results from older wood of deciduous azaleas
do.		Kirkpatrick 1939	May	IBA talc 12,000 p.p.m.	8	75	25	
A. sp. " Carmen "		Yerkes 1938	June	IBA 30 to 100 p.p.m. 4 hrs.	6	100	30	Twigs in active growth
do. *cattleya*		Yerkes 1938	Aug.	IBA 50 to 100 p.p.m. 4 hrs.	5	79	0	Short laterals better than main branches

A. Sp. "Christmas Cheer"		Yerkes 1938	June	IBA 50 p.p.m. 4 hrs.	7	60	100	Short laterals better than main branches
do. "Coral Bells"		Kirkpatrick 1940	June	IBA talc 2,000 p.p.m.	5	100	100	Leaf-mallet cuttings
do. "Damask Rose"		Yerkes 1938	July	IBA 30 to 80 p.p.m. 4 hrs.	5	95	65	Short laterals better than main branches
do. "Debutante"		Yerkes 1938	June	IBA 50 p.p.m. 4 hrs.	5	89	61	Short laterals better than main branches
do. "Firefly"		Yerkes 1938	July	IBA 30 to 100 p.p.m. 18 hrs.	8	95	94	Short laterals better than main branches
do. "Flame"		Kirkpatrick 1940	June	IBA talc 2,000 p.p.m.	5	100	100	Leaf-mallet cuttings
A. spp. "Hexe"		Hubert and Beke 1938	Jan.	IAA 50 p.p.m. 8 hrs.	4	85	40	
do. "Pink Pearl"		Kirkpatrick 1939	June	IBA talc 2,000 p.p.m.	5	100	100	Leaf-mallet cuttings
do. "Snow"		Yerkes 1938	June	IBA 30 p.p.m. 21 hrs.	8	80	33	
A. obtusa Lindl. var. *hinodegirii*		Yerkes 1938	July	IBA 30 to 100 p.p.m. 20 hrs.	7	85	75	
do. var. *hinomayo*		Yerkes 1938	June	IBA 50 to 80 p.p.m. 20 hrs.	6	81	66	
do. var. *yayegiri*		Yerkes 1938	July	IBA 50 p.p.m. 4 hrs.	7	100	67	
A. japonica A. Gray		Yerkes 1938	June	IBA 50 to 100 p.p.m. 4 hrs.	9	35	0	
A. kaempferi		Yerkes 1938	July	IBA 50 to 80 p.p.m. 4 hrs.	7	85	0	
do.		Skinner 1938	Aug.	IBA 90 p.p.m 8 hrs.	4	100	100	More roots
A. maxwellii Hort.		Yerkes 1938	June	IBA 30 to 80 p.p.m. 20 hrs.	7	100	82	
A. mollis		Yerkes 1938	June	IBA 30 to 100 p.p.m. 4 hrs.	10	70	10	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
A. mollis		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	12·5	0	
A. nudiflora L.		Yerkes 1938	June	IBA, 80 to 100 p.p.m. 4 hrs.	9	73	56	Wood in active growth
A. poukhanensis		Yerkes 1938	June	IBA 80 to 100 p.p.m. 4 hrs.	9	67	57	
A. viscosa L.		Yerkes 1938	June	IBA 80 p.p.m. 4 hrs.	9	58	63	
Begonia semperflorens Link. and Otto	Perpetual Begonia	Maxon, Pickett and Richey 1940	Jan.	IBA 5 p.p.m. 24 hrs. (Hormodin)	7	40*	27*	More cuttings rooted
Benzoin aestivale Nees	Spice Bush	Chadwick 1937	July	IBA 40 p.p.m. 24 hrs.	24	—	—	No benefit
B. thunbergii DC. var. *pluriflora erecta* Koehne	Barberry	Chadwick 1937	July	IBA 10 p.p.m. 6 hrs.	7	47	32	
B. thunbergii DC.		Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	4	27*	0*	Some benefit : hardwood cuttings
Berberis vulgaris L. var. *atropurpurea* Regel		Chadwick 1937	Aug.	IPA 100 p.p.m. 24 hrs.	6	45	0	
Betula nana L. var.	Dwarf Birch	Metcalfe and Templeman 1939	Sept.	IAA 50 p.p.m. 24 hrs.	—	—	—	More cuttings rooted
Betula pendula Roth var. *youngii* Schneid.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	10	0	
do. var. *viscosa* Rehd.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
B. pendula var. *fastigiata* Hort.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	5	21	0	

Bougainvillea glabra Choisy	Bougainvillea	Maxon, Pickett and Richey 1940	Nov.	IBA 20 p.p.m. 24 hrs. (Hormodin)	7	62*	7*	Many more cuttings rooted
B. spectabilis Willd. var. " Crimson Lake "		Laibach 1937	—	IAA 0·5 per cent. lanolin paste	7	35	0	
Buddleia spp.	Buddleia	Laibach 1937	—	IAA 100 p.p.m.	2	70	0	
B. alternifolia Maxim.		Metcalfe and Templeman 1939	June	IBA 50 p.p.m. 24 hrs.	2	—	—	More cuttings rooted. More roots per cutting
do.		Chadwick 1937	July	NAA lanolin 1 per cent. paste	—	—	—	Rooted quicker
B. asiatica Lour.		Maxon, Pickett and Richey 1940	March and May	IBA 2·5-5 p.p.m. 24 hrs. (Hormodin)	3	73-80*	36-46*	More cuttings tooted
B. davidii Franch.		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5-5 p.p.m. 24 hrs. (Hormodin)	2	57-60*	2-15*	More cuttings rooted
Bulbophyllum careyanum Spreng.	Orchid	Curtis 1941	March	NAD talc dust	8	60	60	When given supplementary vitamin B_1 1 p.p.m. weekly rooted 100 per cent.
Buxus harlandii Hance	Harland's Box	Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs.	—	—	—	Beneficial
B. microphylla Sieb. and Zucc.	Japanese Little-leaf Box	Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs. IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.	Korean Little-leaf Box	Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs. IBA talc 12,000 p.p.m.	—	—	—	Beneficial
B. quadrangularis F. Muell.		Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
B. sempervirens L.	Common Box	Maxon, Pickett and Richey 1940	March	IBA 80 p.p.m. 24 hrs. (Hormodin)	9	70*	5*	More cuttings rooted
B. sempervirens L. var. *arborescens* L.		Yerkes 1938	Oct.	IBA 30 to 50 p.p.m. 20 hrs.	10	70	33	Cuttings taken earlier yielded similar results

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
B. sempervirens L. var. *arborescens* L.		Kirkpatrick 1940	—	IBA 40 p.p.m. 24 hrs. IBA talc 12,000 p.p.m.	—	—	—	More cuttings rooted
B. sempervirens L. var. *handsworthii* Koch		Yerkes 1938	Oct.	IBA 30 p.p.m. 20 hrs.	10	100	70	
do.		Kirkpatrick 1940	—	IBA 40 p.p.m. 24 hrs. IBA talc 12,000 p.p.m.	—	—	—	More cuttings rooted
Callicarpa purpurea Juss.	Beautyberry	Yerkes 1938	July	IBA 30-100 p.p.m. 20 hrs.	3	100	87	Easily rooted at different stages of growth
C. japonica Thunb.		Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	3	65*	10*	More cuttings rooted
Calluna vulgaris Salisb.	Heather	Kirkpatrick 1940	—	IBA 20-40 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	More cuttings rooted
Calycanthus floridus L.	Carolina Allspice	Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
C. occidentalis Hook. and Arn.		Warner and Went 1939	June	IAA 100 p.p.m. 20 hrs.	—	0	0	Hardwood and softwood cuttings
Camellia japonica L.	Camellia	Williams 1943	Dec.	IBA (Hormodin)	12	88	44	Leaf bud cuttings
do.		Warner and Went 1939	Feb. March	IAA 200 p.p.m. 24 hrs.	3 + 2	70	0	Cuttings treated in Feb. and re-treated March
C. japonica L. var. *alba plena* Lodd.		Kirkpatrick 1939	—	IBA 40 and 80 p.p.m. 24 hrs. IBA talc 12,000 p.p.m.	—	—	—	Re-treatment after callus formation effective
C. japonica L. (*chandleri elegans*).		Kirkpatrick 1939	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. japonica L. var. *magnoliaeflora* Hort.		Cox 1937	July and Aug.	IAA 100 p.p.m. 18 hrs.	5	—	—	More cuttings rooted

C. sasanqua Thunb.		Cox 1937	July and Aug.	IAA 100 p.p.m. 30 hrs.	—	—	—	No benefit
Campsis radicans Selm.	Trumpet Creeper	Laibach 1937	—	IAA	—	—	—	Some benefit
do.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	100	100	More roots per cutting
Cananga odorata Hook. f. and Thoms.	Ilang-ilang	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Caragana arborescens Lam. var. *pendula* Dippel	Pea Tree	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	67	67	More roots
C. frutex Koch		Maxon, Pickett and Richey 1940	Nov.	IBA 20 p.p.m. 24 hrs. (Hormodin)	8	62*	45*	More cuttings rooted
C. pygmaea DC.		Scholz 1937	July	IAA 20 p.p.m. 24 hrs.	5	8	0	
Carica papaya L.	Papaya	Traub 1937	—	IBA 100 p.p.m. 42 hrs.	—	50	28	
do.		Cooper 1938	—	IAA 200 p.p.m.	—	—	—	Re-treatment after callus formation helped rooting
Carpinus betulus L.	European Hornbeam	Chadwick 1937	Nov.	IBA and IAA 50-100 p.p.m. 40 hrs.	—	—	—	No benefit
Carrierea calycina Franch.	Carrierea	Metcalfe and Templeman 1939	July and Sept.	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Carya pecan Engler and Graebn.	Pecan	Stoutemyer 1938	April	IBA 100 p.p.m. 24 hrs.	—	63	0	Wood 2 to 4 years old callused 3 weeks before treatment
Caryopteris incana Miq.	Common Bluebeard (Blue Spirea)	Maxon, Pickett and Richey 1940	April	IBA 20 p.p.m. 24 hrs. (Hormodin)	5	97*	70*	More cuttings rooted
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	60*	7*	More cuttings rooted

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Cassine maurocenia L.	Hottentot Cherry	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Ceanothus arboreus Greene	Ceanothus	Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
C. × *Ceanothus burkwoodii* Hort.		Metcalfe and Templeman 1939	July	IAA and IBA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted. More roots per cutting
C. " Autumnal Blue "		Metcalfe and Templeman 1939	July	IAA, IBA and NAA 50 24 hrs.	5	—	—	More cuttings rooted
C. cyaneus " Eastwood "		Warner and Went 1939	May	IAA 200 p.p.m. 24 hrs.	6	25	0	Hardwood cuttings
do.		Warner and Went 1939	May	IAA 200 p.p.m. 24 hrs.	6	90	0	Softwood cuttings
C. " Gloire de Versailles "		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	7	—	—	More cuttings rooted
C. " Henri Defosse "		Metcalfe and Templeman 1939	July	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Rooted easily without treatment
C. hybridus Hort. " Marie Simon "		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	100	60	
C. ovatus Desf.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	6	37*	5*	More cuttings rooted
C. thyrsiflorus Esch.		Metcalfe and Templeman 1939	Sept.	IAA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted

C. × *C. veitchianus* Hook.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit, many cuttings died
Celastrus scandens L.	False Bitter-sweet	Yerkes 1938	July	IBA 50 p.p.m. 24 hrs.	5	90	0	Cuttings from vines in active growth
do.		Chadwick 1937	July	IBA 30 p.p.m. 6 hrs.	7	100	0	
Centaurea gymnocarpa Moris and DeNot	Velvet Cornflower	Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	3	50*	7*	More cuttings rooted
Cephalanthus occidentalis L.	Buttonbush	Scholz 1937	July	IAA 20-200 p.p.m. 24 hrs.	4	100	100	More roots per cutting
Cerastium tomentosum L.	Snow-in-summer	Maxon, Pickett and Richey 1940	Nov.	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	67*	12*	More cuttings rooted
Ceratostigma 2715 G.S.	Ceratostigma	Metcalfe and Templeman 1939	July	IAA 50 p.p.m. 24 hrs.	2	—	—	More cuttings rooted. More roots per cutting
Chaenomeles lagenaria Koidz.	Japanese Quince	Chadwick 1937	July	IBA 10-80 p.p.m. 12 hrs.	—	—	—	No benefit
C. lagenaria Koidz. var. ***umbilicata*** Hort.		Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
Chamaecyparis lawsoniana Parlatore	Lawson's Cypress	Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. lawsoniana var. *fletcheri*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. obtusa Sieb. and Zucc.		Chadwick 1937	Feb.	IBA 20 to 100 p.p.m. 24 hrs.	—	—	—	No benefit
C. obtusa Sieb and Zucc. var. ***aurea*** *crippsi* Beissn.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
C. obtusa Sieb. and Zucc. var. *compacta*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. obtusa Sieb and Zucc. var. *erecta*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. obtusa Sieb. and Zucc. var. *filicoides*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. obtusa Sieb. and Zucc. var. *filiformis* Beissn.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. obtusa Sieb. and Zucc. var. *gracilis*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
C. pisifera Sieb. and Zucc. var. *filifera*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do. var. *filifera aurea*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do. var. *plumosa*		Yerkes 1938	Oct.	IBA 30 to 80 p.p.m. 20 hrs.	10	65	15	
do. var. *plumosa aurea*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do. var. *plumosa nana*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
Chimonanthus fragrans Lindl. var. *luteus* Hort.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit

Chorizema varium Benth.	Flame Pea	Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	4	100	30	More cuttings rooted. More roots per cutting.
Chrysanthemum frutescens L.	Marguerite	Maxon, Pickett and Richey 1940	Dec. and Feb.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	2	90*	27-48*	Many more cuttings rooted
C. morifolium Ram. (Several varieties)	Chrysanthemum	Maxon, Pickett and Richey 1940	Nov. Dec. Jan. Mar.	IBA 2·5 p.p.m. and 5 p.p.m. 24 hrs. (Hormodin)	2-3	72-97*	6-73*	Many more cuttings rooted and more roots per cutting
C. indicum L.		Turezkaya 1938	—	IAA 100 to 250 p.p.m. 48-56 hrs.	—	—	—	More roots per cutting and quicker rooting
Cinnamomum camphora Nees and Eberm.	Camphor Tree	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	Slight benefit
Cissus rhombifolia	Treebine	Maxon, Pickett and Richey 1940	Feb.	IBA 10 p.p.m. 24 hrs. (Hormodin)	5	90*	10*	Many more cuttings rooted
Cistus "Silver Pink"		Metcalfe and Templeman 1939	June	IBA 50 p.p.m. 24 hrs.	5	—	—	Definite response
Citrus aurantifolia (2 varieties) Swingle	Lime	Cooper 1940	Feb. March	IAA 200 p.p.m. 24 hrs.	3	100	100	More roots per cutting
C. aurantium L.	Sour Orange	Biale 1939	June	IAA 100 p.p.m. 24 hrs.	—	90	60	
C. limonia Osbeck	Lemon	Turezkaya 1938	—	IAA 100 to 250 p.p.m. 48-60 hrs.	—	—	—	More roots per cutting
do.		Cooper 1936	—	IAA 500 p.p.m.	6	—	—	More roots per cutting
Citrus nobilis Lour. var. *unshiu* Swingle	Satsuma Orange	Biale 1939	June	IAA 200 p.p.m. 24 hrs.	—	70	30	
C. paradisi	Marsh Grapefruit	Biale 1939	June	IAA 500 p.p.m. 24 hrs.	—	80	10	
C. sinensis Osbeck	Orange	Hubert and Beke 1938	Jan.	IAA 100 p.p.m. 8 hrs.	3	100	60	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
C. sinensis " Hamlin "		Cooper 1938	—	IAA 200 p.p.m. 24 hrs.	6	—	—	Re-treatment after 3 weeks. Several cuttings rooted
do. " Navel "		Biale 1939	June	IAA 200 p.p.m. 24 hrs.	—	40	30	
do. " Valencia "		Biale 1939	June	IAA 500 to 700 p.p.m. 24 hrs.	—	50	30	
C. sinensis × *Poncirus trifoliata*	Morton Citrange	Cooper 1940	Feb. Mar.	IAA 200 p.p.m. 24 hrs.	6	80	0	
Cladrastis lutea C. Koch	Yellowwood	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	100	100	More roots per cutting
Clematis montana Buch. Ham. var.	Clematis	Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	12	—	—	More cuttings rooted
C. paniculata Thunb.		Maxon, Pickett and Richey 1940	July	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	75*	3*	Many more cuttings rooted
Clerodendron Bungei Steud.	Glorybower	Warner and Went 1939	Dec.	IAA 200 p.p.m.	5	100	20	Given re-treatment after 2 weeks
C. thompsonae Balf.		Maxon, Pickett and Richey 1940	Feb.	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	72*	53*	More cuttings rooted
Codiaeum variegatum Blume	Variegated Laurel	Maxon, Pickett and Richey 1940	Feb.	IBA 20 p.p.m. 26 hrs. (Hormodin)	5	60*	3*	Many more cuttings rooted
Coffea arabica L.	Coffee	Stoutemyer 1939	—	IAA 100 p.p.m. 18 hrs.	9	79	7	New growth used for cuttings
Coleus blumei Benth.	Coleus	Covas 1940	—	IAA 12-24 hrs.	—	—	—	Beneficial
Cordyline stricta Endl.	Dracaena	Laibach 1937	—	IAA lanolin 612·5 p.p.m.	5	80	38	

Coriaria spp.	Coriaria	Stoutemyer 1939	July	NAA talc 1,000 p.p.m.	3	85	58	
Cornus alba L.	Dogwood	Laibach 1937	—	IAA lanolin 0·5 per cent.	36	3	50	
C. amomum Mill.		Yerkes 1938	July	IBA 30 p.p.m. 20 hrs.	3	73	53	
C. florida L.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	25	0	
C. florida var. *rubra* André		Yerkes 1938	July	IBA 50 p.p.m. 4 hrs.	4	60	0	
C. kousa Buerg. var. *chinensis* Osborn		Metcalfe and Templeman 1939	Sept.	IBA and NAA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted
C. mas L.		Chadwick 1937	July	IBA 5-30 p.p.m. 24 hrs.	—	—	—	No benefit
C. macrophylla Wall.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit, cuttings died
C. nuttallii Audub.		Metcalfe and Templeman 1939	June	NAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted. July and Aug. cuttings died
C. paniculata L'Hérit.		Yerkes 1938	July	IBA 80-100 p.p.m. 4 hrs.	6	66	0	
C. purpusii Koehne		Laibach 1937	—	IAA lanolin 0·5 per cent.	36	73	28	
C. sanguinea L.		Chadwick 1937	June	IBA 30 p.p.m. 12 hrs.	3	68	44	
Corylus avellana L.	Hazel or Filbert	Komissarov 1938	Summer	IAA 100 p.p.m. 24 hrs.	—	22	0	Softwood cuttings. Spring cuttings root easily
do. var. *atropurpurea* Kirchn.		Scholz 1937	July	IAA 50 p.p.m. 24 hrs.	4	7	0	
do. var. *pendula* Goesch.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	13	0	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
C. sp.		Swartley 1940	July	IBA talc 4,000 p.p.m.	8	52	0	
Cotinus americanus Nutt.	Smoke Tree	Metcalfe and Templeman 1939	July	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
Cotinus coggygria Scop. var. *purpureus* Rehd.		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	—	—	—	More cuttings rooted
Cotoneaster adpressa Boiss.	Cotoneaster	Chadwick 1937	Aug.	IBA 30 p.p.m. 24 hrs.	—	—	—	No benefit
C. apiculata		Chadwick 1937	June	IBA 10-50 p.p.m. 6 hrs.	—	—	—	No benefit
C. buxifolia Baker		Laibach 1937	—	IAA	—	—	—	Slight benefit
C. dielsiana Pritz.		Chadwick 1937	July	IAA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
C. divaricata Rehd. and Wilson		Chadwick 1937	Aug.	IAA, IBA or IPA 10-100 p.p.m. 5-24 hrs.	—	—	—	No benefit
C. foveolata Rehd. and Wilson		Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
C. glabrata Rehd. and Wilson		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	7	—	—	No benefit. Equally rooted
C. horizontalis Dcne.		Chadwick 1937	July Aug.	IBA 5-30 p.p.m. 24 hrs.	—	—	—	No benefit
C. microphylla Wall.		Yerkes 1938	Oct.	IBA 80 p.p.m. 4 hrs.	3	100	45	Hardwood cuttings
C. moupinensis floribunda Stapf		Chadwick 1937	June Aug.	IBA 5-80 p.p.m. 10-24 hrs.	—	—		No benefit

C. racemiflora Koch var. *soongarua* Schneid.		Maxon, Pickett and Richey 1940	Oct.	IBA 20-80 p.p.m. 24 hrs. (Hormodin)	5	1*	0*	Little benefit
C. simonsii Baker		Chadwick 1937	Aug.	IBA 5-30 p.p.m. 24 hrs.	—	—	—	No benefit
C. zabelii Schneid.		Chadwick 1937	June July	IBA 5-50 p.p.m. 6 to 24 hrs.	—	—	—	No benefit
Crataegus pyracantha Pers.	Pyracantha	Laibach 1937	—	IAA	—	—	—	No benefit
Cryptomeria japonica Don	Cryptomeria	Kirkpatrick 1939	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
Cunonia capensis L.	Cunonia	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Cupressus macrocarpa Hartw.	Monterey Cypress	Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. IAA talc 12,000 p.p.m.	—	—	—	Beneficial
Cydonia oblonga Mill. var. (Quince A)	Quince	Lek and Krijthe 1937	Sept.	IAA 25 p.p.m. 24 hrs.	5	60	20	
C. var. (Quince B)		Lek and Krijthe 1937	Sept.	IAA 25 p.p.m. 24 hrs.	—	—	—	Slight benefit
C. var. (Quince C)		Lek and Krijthe 1937	Sept.	IAA 25 p.p.m. 24 hrs.	—	80	20	
Cytisus attleyanus Hort.	Broom	Scholz 1937	Sept.	IAA 200 p.p.m. 24 hrs.	5	90	10	
C. battandieri Maire.		Metcalfe and Templeman 1939	Sept.	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
C. canariensis Kuntze		Maxon Pickett and Richey 1940	Dec.	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	52*	0*	More cuttings rooted
C. maderensis Masf.		Hitchcock and Zimmerman 1937	—	IAA 40 p.p.m. 24 hrs.	2	—	—	Soft wood cuttings rooted better after treatment

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
C. scoparius Link var. *pendulus* Nichols.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
Dahlia spp. (several varieties)	Dahlia	Kirkpatrick 1939	—	IBA 20-40 p.p.m. 24 hrs.	—	—	—	More roots per cutting
Daphne cneorum L.	Daphne	Chadwick 1937	July	IBA 10-80 p.p.m. 10 hrs.	—	—	—	No benefit
D. laureola L.		Lek and Krijthe 1937	Nov.	IAA 100 p.p.m. 24 hrs.	12	100	0	Some untreated cuttings rooted later
D. odora Thunb.		Warner and Went 1939	Aug.	IAA 200 p.p.m. 24 hrs.	5	60	0	Re-treatment caused more cuttings to root
D. pontica L.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted
Datura cornucopia Hort.	Thorn Apple	Warner and Went 1939	April	IAA 200 p.p.m. 24 hrs.	2	100	40	
Davidia involucrata Baillon	Dove Tree	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	33	0	
Deutzia corymbosa R. Brown	Deutzia	Laibach 1937	—	IAA	—	—	—	Slight benefit
D. crenata Sieb. and Zucc.		Laibach 1937	—	IAA	—	—	—	No benefit
do.		Tincker 1938	July	IAA 100 p.p.m. 24 hrs.	3	—	—	20 per cent. more cuttings rooted
D. gracilis Sieb. and Zucc.		Yerkes 1938	Aug.	IBA 80 to 100 p.p.m. 4 hrs.	2	90	79	Easily rooted at any time
D. longifolia Franch.		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	10	90*	80*	More roots

D. lemoinei Hort.		Chadwick 1937	July	IBA 5-20 p.p.m.	—	—	—	No benefit
do.		Grace 1941	Aug.	IAA talc 1,000 p.p.m.	4	40	20	
D. scabra Thunb. var. *plena*		Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	6	78*	85*	No benefit
D. scabra Thunb. var. *pleniflora*		Maxon, Pickett and Richey 1940	Nov.	IBA 5 p.p.m. 24 hrs. (Hormodin)	6	50*	55*	No benefit
D. scabra Thunb. var. *watereri* Rehd.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	38*	5*	More cuttings rooted
Dianthus caryophyllus L. (many varieties)	Carnation	Maxon, Pickett and Richey 1940	Oct. to April	IBA 5-20 p.p.m. 24 hrs. (Hormodin)	1-4	45-92*	10-57*	More cuttings rooted. More roots per cutting
do.		Kirkpatrick 1939	—	IBA 5 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	—	—	—	Quicker rooting and more roots
Diervilla florida Sieb. and Zucc.	Weigela	Tincker 1938	July	IAA 100 p.p.m. or NAA 100 p.p.m. 24 hrs.	3	—	—	20 per cent. more cuttings rooted
do.		Laibach 1937	—	IAA 100 p.p.m.	4	55	20	
do.		Chadwick 1937	June	IBA 50 p.p.m. 12 hrs.	3	72	0	
do.		Grace 1941	Aug.	IAA talc 1,000 p.p.m.	7	27	13	Soft wood cuttings
D. hybrida Hort.		Chadwick 1937	Aug.	IBA 50 p.p.m. 24 hrs.	4	95	30	
D. lonicera Mill.		Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	3	50*	10*	More cuttings rooted
D. × *D. hybrida* Klenert. var. *styriaca* Klenert.		Metcalfe and Templeman 1939	June	IBA and NAA 20 p.p.m. 24 hrs.	2	—	—	More cuttings rooted
Dipelta floribunda Maxim.	Dipelta	Metcalfe and Templeman 1939	June	NAA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Ehretia thyrsiflora Nakai		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	9	—	—	More cuttings rooted
Elaeagnus angustifolia L.	Oleaster	Maxon, Pickett and Richey 1940	Oct.	IBA 40 p.p.m. 24 hrs. (Hormodin)	5	20*	0*	More cuttings rooted
E. pungens Thunb.		Yerkes 1938	Oct.	IBA 30 p.p.m. 4 hrs.	10	100	72	Earlier and later cuttings did not root
E. pungens Thunb. var. *reflexa* Rehd.		Chadwick 1937	Oct.	IBA, IAA and IPA 100 p.p.m. 21 hrs.	—	—	—	No benefit
Emmenopterys henryi Oliv.	Crowberry	Metcalfe and Templeman 1939	June and July	IBA, IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
Enkianthus perulatus Schneid.	Enkianthus	Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	5	100	100	Better root system
Epidendrum radicans Pav.	Orchid	Curtis 1941	March	NAD talc	8	100	0	Stem sections. Vit. B_1 applied weekly 5 c.c. of 1 p.p.m.
Erica arborea L. var. *alpina* Dieck.	Heath	Tincker 1938	Sept.	NAA 100 p.p.m. 24 hrs.	2	—	—	50 per cent. more cuttings rooted
do.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
E. australis L.		Tincker 1938	Sept.	NAA 100 p.p.m. 24 hrs.	—	—	—	Slight benefit
do. var.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died

E. caffra (?L.)		Tincker 1938	Dec.	IAA 100 p.p.m. 24 hrs.	—	—	—	Slight benefit
E. darleyensis		Skinner 1938	July	IBA 10 p.p.m. 8 hrs.	4	100	77	
E. melanthera L.		Tincker 1938	Dec.	IAA or NAA 100 p.p.m. 24 hrs.	8	—	—	IAA 20 per cent. and NAA 72 per cent. more cuttings rooted
E. multicaulis Salisb.		Tincker 1938	Sept. Oct.	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	Slight benefit
E. vagans L.		Tincker 1938	Sept.	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	20 per cent. more cuttings rooted
E. watsonii Jacks		Tincker 1938	Sept.	NAA 100 p.p.m. 24 hrs.	—	—	—	50 per cent. more cuttings rooted
E. sp.		Kirkpatrick 1940	—	IBA 40 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	More cuttings rooted
Erinacea pungens Boiss.	Erinacea	Tincker 1938	Dec.	IAA 20 p.p.m. 24 hrs.	—	—	—	No benefit
Eriostemon sp.	Eriostemon	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Erythrina corallodendron L.	Coral Tree	Warner and Went 1939	May	IAA 200 p.p.m. 24 hrs.	3	100	0	
Escallonia langleyensis Vilm. and Boiss.	Escallonia	Tincker 1938	July	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	50 per cent. more cuttings rooted
Eucalyptus globulus Labill.	Blue Gum	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Eucommia ulmoides Oliver	Eucommia	Tincker 1938	July	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit
Eucryphia glutinosa Focke	Eucryphia	Metcalfe and Templeman 1939	June July	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
Euonymus alata Maxim.	Spindle Tree	Chadwick 1937	June	IBA 10 p.p.m. 18 hrs.	7	76	44	
E. colorata		Chadwick 1937	June	IBA 30 p.p.m. 6 hrs.	3	100	100	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
E. europaea L.		Chadwick 1937	Aug.	IBA 100 p.p.m. 21 hrs.	6	80	0	
E. fortunei		Chadwick 1937	Aug.	IBA 100 p.p.m. 21 hrs.	5	80	65	
E. fortunei vegeta		Chadwick 1937	Aug.	IBA 100 p.p.m. 21 hrs. (Hormodin)	5	80	65	
E. japonica L.		Maxon, Pickett and Richey 1940	March	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	43*	0*	More cuttings rooted
E. minima		Chadwick 1937	Aug.	IBA 100 p.p.m. 24 hrs.	6	100	87	
E. patens Rehd.		Yerkes 1938	Oct.	IBA 50 p.p.m. 4 hrs.	2	91	40	Easily rooted. Earlier cuttings respond similarly
do.		Chadwick 1937	July	IBA 10 p.p.m. 24 hrs.	4	100	16	
Eupatorium riparium Regel	Mist-Flower	Maxon, Pickett and Richey 1940	May	IBA 5 p.p.m. 24 hrs. (Hormodin)	2	87*	85*	More roots per cutting
Euphorbia pulcherrima Willd.	Poinsettia	Maxon, Pickett and Richey 1940	June	IBA 20 p.p.m. 24 hrs. (Hormodin)	3	70*	23*	More cuttings rooted. Hardwood
do.		Maxon, Pickett and Richey 1940	June and Jan.	IBA 15 p.p.m. 24 hrs. (Hormodin)	3	51*	33*	More cuttings rooted. Softwood Jan. cuttings did not respond
do.		Kirkpatrick 1940	May	IBA 40 p.p.m. 24 hrs.	4	—	—	More and better roots
E. splendens Bojer	Crown of Thorns	Maxon Pickett and Richey 1940	March	IBA 20 p.p.m. 24 hrs. (Hormodin)	5	50*	23*	More cuttings rooted
Euphoria litchi	Euphoria	Hubert and Beke 1938	—	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit

Eurya japonica Thunb.	Eurya	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Exochorda racemosa Rehd.		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
Fabiana imbricata Ruiz and Pav. f. *violacea* Hort.	Peru False Heath	Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted
Fagus sylvatica var. *pendula* Lodd.	Beech	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	50	0	
Feijoa sellowiana Berg.	Pineapple guava	Tincker 1938	Jan.	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit
do.		Metcalfe and Templeman 1939	Sept.	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died
Ficus carica L.	Fig	Cooper 1935	Feb.	IAA lanolin 500 p.p.m.	3	—	—	More roots per cutting
F. carica L. (Calimyrna)		Warner and Went 1939	March	IAA 200 p.p.m. 24 hrs.	5	100	80	
F. sp. ***cyatistipula*** (?) Warb.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	4	80	90	Treated cuttings had more roots
F. ***porteana*** Regel		Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	Very little benefit
F. retusa L.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 24 hrs.	2	90	0	
F. ***rubiginosa*** Desf.		Hubert and Beke 1938	Jan.	IAA 100 p.p.m. 8 hrs.	3	40	13	
Fontanesia fortunei Carr.	Fontanesia	Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	9	53*	0*	More cuttings rooted
Forsythia intermedia Zabel	Forsythia	Oliver 1938	June	IBA 40 p.p.m. 24 hrs.	5	20	0	
do.		Oliver 1938	July	IBA 40 p.p.m. 24 hrs.	6	60	0	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
F. intermedia var. *primulina* Rehd.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 and 20 p.p.m. 24 hrs. (Hormodin)	3	60-77*	20-30*	More cuttings rooted
F. intermedia var. *spectabilis* Spaeth.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	70*	45*	More cuttings rooted
F. × *F. intermedia* Zabel var. *spectabilis* Spaeth.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
F. suspensa Vahl		Tincker 1938	June	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	Quicker rooting
do.		Chadwick 1937	June	IBA 50 p.p.m. 6 hrs.	4	80	40	
Fortunella hindsii Swingle	Hong Kong Kumquat	Cooper and Knowlton 1940	Feb. March	IAA 200 p.p.m. 24 hrs.	8	40	40	Treated cuttings had more and longer roots
F. sp.		Warner and Went 1939	Dec. Jan.	IAA 200 p.p.m. 24 hrs.	5	70	0	Cuttings treated in Dec. and retreated in Jan. rooted after second treatment
Fothergilla alnifolia L. f.	Dwarf Alder	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	100	100	
F. gardenii Murr. var *glauca* Hort.		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
F. major Lodd.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
F. monticola Ashe		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	7	—	—	No benefit. All equally rooted

Frankenia alatamaha	Frankenia	Yerkes 1938	Aug.	IBA 30 p.p.m. 4 hrs.	4	100	0	
Fuchsia macrostemma Ruiz and Pav.		Tincker 1938	Sept.	IAA, IBA or NAA 25 p.p.m. 24 hrs.	3			80 per cent. more cuttings rooted
F. speciosa Hort.		Maxon, Pickett and Richey 1940	Jan.	IBA 5 p.p.m. 24 hrs. (Hormodin)	5	87*	5*	
do.		Maxon, Pickett and Richey 1940	March	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	75*	5*	
do.		Maxon, Pickett and Richey 1940	Feb.	IBA 5 p.p.m. 26 hrs. (Hormodin)	2	82*	2*	
Galphimia brasiliensis A. Juss.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	3	90	70	Many more roots per cutting
Gardenia jasminoides Ellis	Cape Jasmine	Covas 1939	—	IAA 12-24 hrs.	—	—	—	Beneficial
G. veitchii		Maxon, Pickett and Richey 1940	March	IBA 5 p.p.m. 24 hrs. (Hormodin)	6	23*	0*	
G. sp.		Kirkpatrick 1940	—	IBA 40 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	—	—	—	Beneficial
do.	Gardenia	Warner and Went 1939	July	IAA 200 p.p.m. 24 hrs.	4	100	0	
Garrya elliptica Dougl.	Garrya	Metcalfe and Templeman 1939	July	IAA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
Gaultheria procumbens L	Winter Green	Tincker 1938	March	IAA or NAA 100 p.p.m. 24 hrs.	—	—	—	IAA 35 per cent. and NAA 51 per cent. more cuttings rooted
Genista horrida DC. var. *erinacea* Hort.	Gorse	Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Gentiana sino-ornata Balf. f.	Chinese Gentian	Hubert and Beke 1938	Oct.	IAA 100 p.p.m. 24 hrs.	4	—	—	30 per cent. more cuttings rooted
Ginkgo biloba L.	Maidenhair Tree	Yerkes 1938	July	IBA 50 p.p.m. 20 hrs.	5	90	80	Taken after terminals had formed
Gordonia alatamaha Sarg.		Yerkes 1938	Aug.	IBA 30 p.p.m. 4 hrs.	4	83	34	Taken from young trees after terminal buds had formed
Grevillea sulphurea A. Cunn.		Tincker 1938	Oct.	IAA 20 p.p.m. 24 hrs.	—	—	—	10 per cent. more cuttings rooted
Griselinia littoralis Raoul		Tincker 1938	May	IAA 50 p.p.m. 48 hrs.	—	—	—	Some benefit
G. *lucida* Forst. f.		Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Gypsophila paniculata L.	Gypsophila	Tincker 1938	July	IAA 25 p.p.m. 24 hrs.	2	100	100	Untreated and treated cuttings rooted 100 per cent.
Halesia carolina L.	Snowdrop Tree	Chadwick 1937	July	IBA 10-80 p.p.m. 10 hrs.	—	—	—	No benefit
do.		Scholz 1937	July	IAA 100 p.p.m. 48 hrs.	—	70	—	Positive response
do.		Metcalfe and Templeman 1938	Aug.	IAA IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
do.		Doran 1940	July	IBA 25 p.p.m. 20 hrs.	6	80	40	
H. diptera Ell.		Metcalfe and Templeman 1938	Aug.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
H. carolina L. var. *monticola* Rehd.		Doran 1940	July	IBA 25 p.p.m. 20 hrs.	6	80	40	

Hamamelis virginiana L.	Witch Hazel	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	33	0	
Hedera helix L.	Ivy	Tincker 1938	Jan.	IAA or NAA 100 p.p.m. 24 hrs.	4	100	0	No untreated cuttings rooted in 4 weeks
do.		Chadwick 1937	July	IBA 30 p.p.m. 4 hrs.	2	100	96	
do.		Kirkpatrick 1939	Jan.	IBA talc 2,000 p.p.m.	—	—	—	Quicker rooting
Hedysarum multijugum Maxim.	Mongolian Sweet Vetch	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	20	0	
Helichrysum rupestre DC. var. *helianthemifolium* (*Gnaphalium lanceolatum* ?)	Everlasting Flower	Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 6 hrs.	2	90	40	More roots per cuttings
Hevea brasiliensis Muell.	Para Rubber Tree	Baptiste 1939	—	NAA solution	—	—	—	Marked improvement
Hibiscus rosa-sinensis	Hibiscus	Maxon, Pickett and Richey 1940	Jan.	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	35*	28*	
do.		Maxon, Pickett and Richey 1940	March	IBA 40 p.p.m. 24 hrs. (Hormodin)	5	41*	0*	
Hibiscus syriacus L.		Chadwick 1937	July	IBA 50 p.p.m. 6 hrs.	5	100	52	
do. var. *azureus* Hort.		Metcalfe and Templeman 1939	Aug.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	7	—	—	No benefit. All equally rooted
do. var. *caerulea* Hort.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit, many cuttings died
Humulus lupulus L. var. " Brewer's Gold " (Salmon 1934)	Hop	Bailey 1939	April	IAA 200 p.p.m. 24 hrs.	—	100	50	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Humulus lupulus L. var. " Brewer's Gold " (Salmon 1934)		Bailey 1939	June	IAA 100 p.p.m. 24 hrs.	—	80	0	
do.		Bailey 1939	June	NAA 50 p.p.m. 24 hrs.		80	0	
Hydrangea arborescens L.	Hydrangea	Grace 1940	Nov.	Naphthylhexoic acid (K salt) talc 1,000 p.p.m.	11	87	37	Dormant cuttings
H. integerrima Engl.		Metcalfe and Templeman 1939	Sept.	NAA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted
H. macrophylla DC. var. *veitchii* Wils.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	4	—	—	No benefit. All equally rooted
H. opuloides C. Koch		Warner and Went 1939	Oct.	IAA 200 p.p.m. 20 hrs.	3	66	0	
do.		Tincker 1938	Oct.	IAA 50 p.p.m. 24 hrs.	—	—	—	10 per cent. more cuttings rooted
do.		Maxon, Pickett and Richey 1940	June	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	73*	25*	More cuttings rooted
do. var. *otaksa* Dipp.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	100	100	
H. paniculata Sieb.		Oliver 1938	June	IBA 20 p.p.m. 24 hrs.	4	100	40	
do.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	3	—	—	No benefit. All equally rooted
H. quercifolia Bartr		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	100	100	

H. quercifolia Bartr.		Chadwick 1937	July	IBA 30 p.p.m. 10 hrs.	7	40	0	
H. sargentiana Rehd.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	100	50	
H. scandens DC.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	60	60	
do.		Chadwick 1937	July	IBA 30 p.p.m. 22 hrs.	9	16	0	
Hymenaea courbaril L.		Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Hymenanthera crassifolia Hook. f.	Hymenanthera	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No positive results
Hypericum elatum Ait. var.	St. John's Wort	Metcalfe and Templeman 1939	Sept.	IAA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted. More roots per cutting
H. sp.		Stoutemyer 1939	July	NAA talc 1,000 p.p.m.	3	95	43	
Iberis sempervirens L.	Candytuft	Laibach 1937	—	IAA 100 p.p.m.	4	53	31	
Ilex aquifolium L.	English Holly	Hubert and Beke 1938	Jan.	IAA 100 p.p.m. 8 hrs.	4	75	0	
do.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
I. bullata		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
I. cornuta Lindl.		Yerkes 1938	June	IBA 30 to 80 p.p.m. 4 hrs.	9	30	0	
do.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Williams 1943	Dec.	Rootone or Hormodin	8	36	0	Leaf bud cuttings
do.		Williams 1943	Dec.	Rootone or Hormodin	8	100	20	Stem cuttings

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
I. cornuta Lindl. var. *burfordii*		Williams 1943	Dec.	Rootone	9	100	68	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	9	76	68	do.
do.		Williams 1943	Dec.	Rootone or Hormodin	9	100	100	Stem cuttings
I. crenata Thunb.		Yerkes 1938	June	IBA 80 p.p.m. 4 hrs.	6	100	57	Cuttings from growing wood best
do.		Hitchcock and Zimmerman 1936	—	IBA 20 p.p.m. or NAA 50 p.p.m. 24 hrs.	—	100	—	Rooting quicker and more roots
do.		Chadwick 1937	Aug.	IBA 30 p.p.m. 24 hrs.	7	53	0	
I. crenata Thunb. var. *nummularia* Yatabe		Metcalfe and Templeman 1939	Sept.	IBA or NAA 50 p.p.m. 24 hrs.	6	—	—	More cuttings rooted
do. *microphylla* Maxim.		Yerkes 1938	June	IBA 50 p.p.m. 4 hrs.	9	87	20	Cuttings from growing wood best
I. glabra A. Gray	Inkberry	Yerkes 1938	July	IBA 50 p.p.m. 4 hrs.	6	90	0	Half ripe wood
do.		Chadwick 1937	July	IBA 30 p.p.m. 24 hrs.	4	96	4	
do.		Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	—	—	—	Beneficial
I. integra Thunb.		Williams 1943	Dec.	Hormodin	9	88	0	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	9	100	0	Stem cuttings
I. latifolia Thunb.		Williams 1943	Dec.	Hormodin	11	60	40	Leaf bud cuttings

I. latifolia Thunb.		Williams 1943	Dec.	Rootone or Hormodin	12	100	20	Stem cuttings
I. opaca Ait.	American Holly	Yerkes 1938	Oct.	IBA 100 p.p.m. 18 hrs.	—	96	0	Nearly mature wood
do.		Hitchcock and Zimmerman 1936	Dec.	IAA 20 p.p.m. 6 hrs.	5	100	—	Quicker rooting and more roots
do.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial at any time except early summer
do.		Chadwick 1937	June	IBA 30 p.p.m. 24 hrs.	6	53	0	
do.		Williams 1943	Dec.	Hormodin	11	81	60	Leaf bud cuttings
I. pernyi Franch.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Williams 1943	Dec.	Rootone	13	90	10	Stem cuttings
I. verticillata A. Gray	Winterberry	Laibach 1937	—	IAA	—	—	—	Only slight improvement
do.		Lek and Krijthe 1937	Oct. and Nov.	IAA	—	—	—	No positive results
do.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
Impatiens sp.	Touch-me-not	Warner and Went 1939	Jan.	IAA 200 p.p.m. 24 hrs.	3	100	0	
Iresine herbstii Hook. f.	Bloodleaf	Maxon, Pickett and Richey 1940	Dec. Feb.	IBA 2·5 and 5 p.p.m. 24 (Hormodin)	3-4	72-100*	20-90*	Beneficial
I. lindenii var. Houtte.		Hubert and Beke 1938	Dec.	IAA 50 p.p.m. 24 hrs.	2	100	100	More roots
do.		Grace 1941	Feb.	NBA talc 1,000 p.p.m.	4	100	56	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Jasminum spp.	Jasmine	Warner and Went 1939	March	IAA 100 p.p.m. 24 hrs.	5	100	0	
J. beesianum Forrest and Diels		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	100	50	
J. nudiflorum Lindl.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	73	40	
do.		Laibach 1937	—	IAA lanolin 0·5 per cent.	5	68	16	
J. primulinum Hemsl.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	9	100	40	
J. stephanense Hort.		Scholz 1937	—	IAA	—	—	—	No positive result
J. wallichianum Lindl.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	100	80	
Juniperus chinensis L.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 80 p.p.m. 24 hrs. (Hormodin)	20	35*	0*	More cuttings rooted
J. chinensis L. var. *pfitzeriana* Spaeth		Yerkes 1938	Oct.	IBA 50 to 80 p.p.m. 20 hrs.	12	40	0	Similar results from earlier cuttings
do.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Yerkes 1938	Oct.	IBA 50 to 80 p.p.m. 20 hrs.	12	40	0	
J. chinensis L. var. *pyramidalis* Carr.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 20 and 40 p.p.m. 24 hrs. (Hormodin)	26	30-33*	15-18*	More cuttings rooted

J. communis L. var. *depressa* Pursh		Maxon, Pickett and Richey 1940	Feb.	IBA 40 p.p.m. 24 hrs. (Hormodin)	26	75*	30*	More cuttings rooted
J. communis L. var. *depressa plumosa*		Maxon, Pickett and Richey 1940	April and Oct.	IBA 20 and 40 p.p.m. 24 hrs. (Hormodin)	13-21	35-45*	0-13*	More cuttings rooted
J. communis L. var. *hillii*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. communis L. var. *montana*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. conferta		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. excelsa Bieb.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. horizontalis Moench		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. horizontalis Moench (gray form)		Maxon Pickett and Richey 1940	Oct.	IBA 20-80 p.p.m. 24 hrs. (Hormodin)	20	0*	8*	No benefit
do. (green form)		Maxon, Pickett and Richey 1940	Nov.	IBA 40 p.p.m. 24 hrs. (Hormodin)	17	60*	8*	More cuttings rooted
J. horizontalis Moench var. *plumosa*		Yerkes 1938	Oct.	IBA 50 p.p.m. 20 hrs.	7	60	60	Similar results with Aug. and Sept. cuttings
do.		Chadwick 1937	Feb.	IBA 20 p.p.m. 18 hrs.	3	72	64	
J. sabina var. *procumbens* Pursh		Maxon, Pickett and Richey 1940	April	IBA 80 p.p.m. 24 hrs. (Hormodin)	22	18*	0*	More cuttings rooted
J. rigida Sieb. and Zucc.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
J. sabina L.	Sabine Juniper	Oliver 1938	July	IBA 100 p.p.m. 24 hrs.	7	60	0	
do.		Maxon, Pickett and Richey 1940	Jan.	IBA 40 p.p.m. 24 hrs. (Hormodin)	8	10*	0*	More cuttings rooted
do. var. *tamariscifolia*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do. var. *vonehron*		Chadwick 1937	June	IBA 10-100 p.p.m. 12 hrs.	—	—	—	No benefit
J. squamata Lamb *wilsonii.*		Maxon, Pickett and Richey 1940	Jan.	IBA 40 p.p.m. 24 hrs. (Hormodin)	12	20*	0*	Beneficial
J. virginiana L.		Chadwick 1937	July	IBA 10-100 p.p.m. 24 hrs.	—	—	—	No benefit
J. virginiana L. var. *globosa*		Chadwick 1937	Jan.	IBA 20-100 p.p.m. 18 hrs.	—	—	—	No benefit
J. virginiana L. var. *keteleeri*		Chadwick 1937	Feb.	IBA 20-100 p.p.m. 18 hrs.	—	—	—	No benefit
do.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
J. virginiana L. var. *tripartita*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
Kalmia angustifolia L.	Sheep Laurel	Cox 1937	July and Aug.	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
Kalmia latifolia L.	American Laurel	Tincker 1938	March	IAA 50 p.p.m. 24 hrs.	—	—	—	Inconclusive results
do.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	All cuttings died

Kalmia latifolia L.		Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	19	80	20	Leaf cuttings
do.		Skinner 1938	July	IAA 90 p.p.m. 24 hrs.	18	40	20	Stem cuttings
K. latifolia L. var. *myrtifolia* Bosse		Tinckner 1938	Jan.	IAA 100 p.p.m. 48 hrs.	—	66	12	
Kerria japonica DC	Kerria	Tincker 1938	July	IAA 33 p.p.m. 24 hrs.	—	—	—	Hastened rooting slightly
Kleinia neriifolia Haw.	Kleinia	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	Very little effect
Kolkwitzia amabilis Graebn.	Kolkwitzia	Yerkes 1938	July	IBA 60-100 p.p.m. 4 hrs.	5	100	0	Cuttings taken before terminals formed
do.		Chadwick 1937	June	IBA 80 p.p.m. 10 hrs.	6	92	4	
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 10-40 p.p.m. 24 hrs. (Hormodin)	9	4*	0*	Slightly beneficial
Lantana camara L.	Lantana	Maxon, Pickett and Richey 1940	Jan. Feb. Oct. and Dec.	IBA 5 and 10 p.p.m. 24 hrs. (Hormodin)	3-4	50-90*	0-75*	More cuttings rooted
L. sellowiana Link Link and Otto	Trailing Lantana	Maxon, Pickett and Richey 1940	Feb. Oct. Dec.	IBA 5 and 10 p.p.m. 24 hrs. (Hormodin)	2-4	30-92*	2-72*	More cuttings rooted
Larix decidua Mill.	Larch	Chadwick 1937	July	IBA 10-80 p.p.m. 10 hrs.	—	—	—	No benefit
Laurus camphora L.	Laurel	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	Very little effect
L. nobilis L.		Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	Very little effect
Lavandula vera DC.	Lavender	Laibach 1937	—	IAA	—	—	—	Slight improvement
Leptospermum scoparium Forst. var. *prostratum* Hort.	Leptospermum	Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Leucothoë catesbaei A. Gray	Leucothoë	Skinner 1938	July	IBA 10 p.p.m. 24 hrs.	7-10	100	100	Leaves and stems
L. populifolia Dipp. (*L. acuminata* G. Don)		Metcalfe and Templeman 1939	July	IBA or NAA 50 p.p.m. 24 hrs.	9	—	—	More cuttings rooted
Libocedrus decurrens Torr.	White Cedar	Doran 1940	Nov.	IBA 150 p.p.m. 24 hrs.	9	100	50	All cuttings were kept in sand peat 15 months before treatment
Ligustrum amurense Carr.	Privet	Maxon, Pickett and Richey 1940	July	IBA 80 p.p.m. 24 hrs. (Hormodin)	4	67*	30*	More cuttings rooted. Hardwood
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 40 p.p.m. 24 hrs. (Hormodin)	6	83*	65*	Soft tips. More cuttings rooted
L. ibolium		Chadwick 1937	July	IBA 50 p.p.m. 26 hrs.	5	76	72	
L. ibota Sieb. var. *regelianum* Rehd.		Chadwick 1937	June	IBA 50 p.p.m. 6 hrs.	7	93	87	
do.		Maxon, Pickett and Richey 1940	Oct. and Nov.	IBA 80 p.p.m. 24 hrs. (Hormodin)	6	17-75*	0*	More cuttings rooted. Nov. best
L. japonicum Thunb.		Yerkes 1938	June	IBA 30-50 p.p.m. 20 hrs.	4	95	94	Growing tips rooted quicker than older wood
L. ovalifolium Hassk.		Kirkpatrick 1940	—	IBA 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
L. vulgare L. var. *atrovirens*	Privet	Laibach 1937	—	IAA lanolin 0·5 per cent. paste	3	58	0	Rooted in sand
do.		Laibach 1937	—	IAA lanolin 0·5 per cent. paste	—	20	5	Rooted in water

L. vulgare L. var. *foliosa*		Maxon, Pickett and Richey 1940	Oct.	IBA 80 p.p.m. 24 hrs.	6	36*	0*	More cuttings rooted
do. var. *lowdense*		Maxon, Pickett and Richey 1940	Nov.	IBA 80 p.p.m. 24 hrs. (Hormodin)	6	75*	7*	More cuttings rooted
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 40 p.p.m. 24 hrs. (Hormodin)	10	80	25	More cuttings rooted
Linum flavum **L.**	Golden Flax	Maxon, Pickett and Richey 1940	Oct.	IBA 10 and 20 p.p.m. 24 hrs. (Hormodin)	3	5*	7*	No benefit
Liriodendron tulipifera L.	Tulip Tree	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	33	0	
Liriodendron tulipifera L. var. *fastigiata* Hort.		Metcalfe and Templeman 1939	Aug.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit
Lithodora diffusa	Lithodora	Tincker 1938	Jan.	IAA 25 p.p.m. 24 hrs.	4	—	—	20 per cent. more cuttings rooted. More roots per cutting
Litchi chinensis Sonn.	Litchi	Sen 1947	June Sept.	IBA 50-100 p.p.m. 24 hrs.	13	100	0	2-year-old wood best
Lonicera bella Zabel var. *alba*		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	5	67*	0*	More cuttings rooted. Coarse sand best rooting medium
L. japonica var. *articulata*	Japanese Honeysuckle	Maxon, Pickett and Richey 1940	Jan.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	6	77*	—	More cuttings rooted
L. korolkovii Stapf		Chadwick 1937	Nov.	IAA 100 p.p.m. 40 hrs.	8	80	5	
L. nitida Wilson		Cox 1937	Nov. Dec.	IAA 100 p.p.m. 24 hrs.	5	—	—	Treated cuttings died. Controls rooted
L. pyrenaica L.		Metcalfe and Templeman 1939	July	IAA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
L. standishii Carr.		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	10	27*	17*	More cuttings rooted
L. tartarica L.		Grace 1939	March	IAA 100 p.p.m. 24 hrs.	5	50	3	More roots per cutting
L. yunnanensis		Tincker 1938	Dec.	IAA 50 p.p.m. 24 hrs.	3	—	—	40 per cent. more cuttings rooted
do.		Tincker 1938	Dec.	NAA 50 p.p.m. 24 hrs.	4	—	—	65 per cent. more cuttings rooted
Macadamia ternifolia F. Muell.	Queensland Nut	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Maclura aurantiaca Nutt.	Bow Wood	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	100	66	
Magnolia dawsoniana Rehd. and Wils.	Magnolia	Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
M. denudata Desr.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	80	0	
M. hybrida var. *norbertiana* Hort.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	100	11	
M. kobus Thunb.		Chadwick 1937	Aug.	IBA or NAA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
M. kobus Thunb. var. *borealis* Sarg.		Yerkes 1938	June	IBA 80 to 100 p.p.m. 22 hrs.	3	58	0	Shoots in active growth
M. lennei Topf		Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
M. liliflora Desr.		Yerkes 1938	Aug.	IBA 50 p.p.m. 22 hrs.	7	100	21	Cuttings taken when terminal buds were forming

M. liliflora Desr. var. *nigra* Rehd.		Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	—	—	—	More cuttings rooted
M. parviflora Sieb. and Zucc.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	100	50	
M. salicifolia Maxim.		Metcalfe and Templeman 1938	July	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died
M. sargentiana Rehd. and Wils.		Metcalfe and Templeman 1939	Sept.	IAA, IBA and NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
M. sprengeri Pamp.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
M. soulangeana Soul.		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	6	67	0	
M. × *M. soulangeana* Soul. var. *superba* Hort.		Metcalfe and Templeman 1939	July	IBA 50 p.p.m 24 hrs.	3	—	—	More cuttings rooted
Mahoberberis neuberti var. *latifolia*	Mahoberberis	Chadwick 1937	Aug.	IAA, IBA or IPA 50-100 p.p.m. 24 hrs.	—	—	—	No benefit
Mahonia nevinii Fedde	Mahonia	Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Mangifera indica L.	Mango	Thakurta 1941	—	IAA lanolin 30,000 p.p.m.	—	—	—	Beneficial. Paste applied to young, attached twigs, from which cuttings were taken 24 hrs. later
Maurocenia capensis	Maurocenia	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Maxillaria variabilis Batem.	Orchid	Curtis 1941	March	NAD talc dust	8	70	40	Vit. B_1 (5 ml. of 1 p.p.m.) added weekly caused 100 per cent. rooting
M. variabilis Batem. var. *lutea*		Curtis 1941	March	NAD talc dust	8	100	30	Vit. B_1 (5 ml. of 1 p.p.m.) added weekly
Medicago sativa L.	Alfalfa	Maxon, Pickett and Richey 1940	Nov.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	4	—	—	More cuttings rooted
do.		Covas 1939	—	IAA 12-24 hrs.	—	—	—	Beneficial
Megaclinum purpuratum Lindl.	Orchid	Curtis 1941	March	NAD talc	8	80	60	Vit. B_1 added weekly (5 c.c. of 1 p.p.m.) caused 100 per cent. rooting
Melastoma sp.	Melastoma	Stoutemyer 1937	May	NAA or NAD talc 1,000 p.p.m.	1	100	100	
Meliosma dilleniifolia Wall.	Meliosma	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—		No benefit. All cuttings died
M. veitchiorum Hemsl.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 20 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Menziesia ciliicalyx	Menziesia	Cox 1937	July Aug.	IAA 100 p.p.m. 30 hrs.	4	—	—	No benefit
Mesembryanthemum roseum Willd.	Mesembryanthemum. Fig Marigold	Maxon, Pickett and Richey 1940	Feb.	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	95*	86*	Beneficial
Michelia excelsa Bl.	Michelia	Metcalfe and Templeman 1939	Sept.	NAA 50 p.p.m. 24 hrs.	8	—	—	More cuttings rooted

Monarda didyma L.	Horse Mint	Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	—	32-80*	2-22*	More cuttings rooted
Morus alba L.	White Mulberry	Hubert and Beke 1938	Jan.	IAA 100 p.p.m. 8 hrs.	2	100	66	Basal cuttings rooted better than apical. Pronounced bud inhibition on treated cuttings
do.		Warner and Went 1939	July	IAA 100 and 200 p.p.m. 22 hrs.	4	0	0	Hardwood cuttings. Leaves fell
do.		Warner and Went 1939	July	IAA 100 p.p.m. 22 hrs.	4	76	47	Softwood cuttings
M. nigra L.	Black Mulberry	Hubert and Beke 1938	Jan.	IAA 100 p.p.m. 8 hrs.	4	62	12	
do.		Metcalfe and Templeman 1939	Sept.	NAA 50 p.p.m. 24 hrs.	9	—	—	More roots per cutting
Myrica californica Cham.	Wax Myrtle	Warner and Went 1939	June	IAA 200 p.p.m. 20 hrs.	4	100	12	Softwood cuttings
do.		Warner and Went 1939	June	IAA 100 p.p.m. 20 hrs.	4	25	71	Hardwood cuttings
M. carolinensis Mill.	Bayberry	Chadwick 1937	Aug.	IAA or IBA 50-100 p.p.m. 24 hrs.	—	—	—	No benefit
M. cerifera L.		Williams 1943	Dec.	Rootone or Hormodin	5	56	36	Leaf bud cuttings
M. gale L.		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	5	100	80	
Myrtus pubescens	Myrtle	Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	5	58	0	
M. ugni molina	Chilean Guava	Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	5	58	17	
Nerium oleander L.	Oleander	Maxon, Pickett and Richey 1940	March	IBA 10 p.p.m. 24 hrs. (Hormodin)	5	40*	3*	More cuttings rooted
do.		Maxon, Pickett and Richey 1940	Jan.	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	60*	38*	More cuttings rooted

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Nothofagus antarctica Oerst. var. *uliginosa* Reiche	Nothofagus	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
N. betuloides Blume		Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 20 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
N. dombeyi Blume		Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
N. obliqua Blume		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
N. procera Oerst.		Metcalfe and Templeman 1939	July Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Nyssa sylvatica Marsh	Black Gum	Metcalfe and Templeman 1939	June	IAA, IBA or NAA 20 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
do.		Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Olea europaea L. var. *communis* Ait. " Mission "	Olive	Hartmann 1946	Jan.-April	IBA 40 p.p.m. 24 hrs.	10	30	28	Bottom heat 75° F.-80° F. Humidity 90-100 per cent.
do.		Hartmann 1946	April-July	IBA 12 p.p.m. 24 hrs.	10	76	0	do.
O. europaea L. var. *communis* Ait. " Manganillo "		Hartmann 1946	Jan.-April	IBA 40 p.p.m. 24 hrs.	10	30	8	do.

O. europaea L. var. *communis* Ait. " Mangenillo "		Hartmann 1946	April-July	IBA 50 p.p.m. 24 hrs.	10	79	3	do.
O. europaea L. var. *communis* Ait. " Sevillano "		Hartmann 1946	Jan.-April	IBA 40 p.p.m. 24 hrs.	10	20	0	do.
do.		Hartmann 1946	April-July	IBA 25 p.p.m. 24 hrs.	10	42	0	do.
Olea sp.		Turezkaya 1938	—	IAA 100-200 p.p.m. 48-60 hrs.	—	—	—	1-year-old cuttings. Treatment induced callusing only
Olearia haastii Hook.	Tree Aster	Lek and Krijthe 1937	Nov.	IAA 25 p.p.m. 28 hrs.	5	80	30	
Opuntia sp.	Prickly Pear	Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs.	—	—	—	Beneficial
Osmanthus aquifolium Sieb.	Osmanthus	Yerkes 1938	July	IBA 15 p.p.m. 4 hrs.	5	93	20	
do.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	6	100	55	
do.		Williams 1943	Dec.	Rootone	8	56	56	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	8	100	80	Stem cuttings
O. delavayi Franch.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	4	—	—	No benefit. All equally rooted
O. fortunei Carr.		Williams 1943	Dec.	Hormodin	12	32		Leaf bud cuttings
O. fragrans Lour.		Williams 1943	Dec.	Hormodin	8	36	32	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	8	100	40	Stem cuttings
Oxydendrum arboreum DC.	Sorrel Tree	Skinner 1938	July	IBA 90 p.p.m. 8 hrs.	8	80	0	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Oxydendrum arboreum DC.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Pachysandra terminalis Sieb. and Zucc.	Pachysandra	Chadwick 1937	June	IBA 30 p.p.m. 6 hrs.	4	100	60	
do.		Kirkpatrick 1940	—	IBA 80 p.p.m. 24 hrs. or IBA talc 1,200 p.p.m.	—	—	—	Beneficial
Parrotia persica C. A. Mey.	Parrotia	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	5	100	50	
do.		Metcalfe and Templeman 1939	Aug.	IBA 50 p.p.m. 24 hrs.	12	—	—	More cuttings rooted
Parthenocissus tricuspidata Planch.	Parthenocissus	Maxon, Pickett and Richey 1940	July	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	42*	5*	More cuttings rooted
do.		Chadwick 1937	Aug.	IBA 30 p.p.m. 24 hrs.	3	90	90	
Pelargonium domesticum var. " Lady Washington "	Geranium	Maxon, Pickett and Richey 1940	Feb.	IBA 10 p.p.m. 24 hrs. (Hormodin)	5	62*	10*	
do.		Maxon, Pickett and Richey 1940	June	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	53*	25*	
P. hortorum var. " Mrs. Beach "	Bedding Geranium	Maxon, Pickett and Richey 1940	June	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	80*	2*	
do. " Mrs. Waters "		Maxon, Pickett and Richey 1940	June	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	94*	5*	

P. hortorum var. " Mt. Mort "		Maxon, Pickett and Richey 1940	June	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	72*	15*	
do. " S.A. Nutt "		Maxon, Pickett and Richey 1940	June	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	75*	2*	
do. " Riccard "		Maxon, Pickett and Richey 1940	June	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	62*	12*	
P. peltatum Ait.	Ivy-leaved Geranium	Maxon, Pickett and Richey 1940	Feb.	IBA 10 p.p.m. 24 hrs. (Hormodin)	2	100*	15*	
do.		Maxon, Pickett and Richey 1940	June	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	80*	30*	
P. tricolor		Maxon, Pickett and Richey 1940	Jan.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	6	87*	22*	
Pentstemon barbatus Nutt.	Pentstemon	Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	65*	2*	
Peraphyllum ramosissimum Nutt.	Peraphyllum	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Pereskia saccharosa	Lemon Vine	Covas 1940	—	IAA 12-24 hrs.	—	—	—	Beneficial
Pernettya leucocarpa.	Pernettya	Cox 1937	July Aug.	IAA 100 p.p.m. 30 hrs.	—	—	—	No benefit
Petunia hybrida Hort.	Petunia	Maxon, Pickett and Richey 1940	April	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	72*	45*	
Philadelphus coronarius L.	Syringa	Laibach 1937	—	IAA lanolin 0·5 per cent. paste	36	52	25	
do.		Chadwick 1937	July	IBA 50 p.p.m. 20 hrs.	2	56	8	
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	9	87*	47*	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
P. grandiflorus Willd.		Yerkes 1938	July	IBA 30 to 50 p.p.m. 20 hrs.	5	75	70	Softwood cuttings taken soon after flowering
P. sp. " Glacier "		Metcalfe and Templeman 1939	July	IAA 50 p.p.m. 24 hrs.	9	—	—	More cuttings rooted
P. sp. " Norma "		Yerkes 1938	July	IBA 30 p.p.m. 4 hrs.	—	87	0	Softwood, soon after flowering
P. sp. " Virginal "		Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	9	96*	15*	
P. sp. " Voie Lactée "		Yerkes 1938	July	IBA 80 p.p.m. 8 hrs.	5	42	10	Softwood, soon after flowering
P. microphyllus Gray		Metcalfe and Templeman 1940	July	IAA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
do.		Metcalfe and Templeman 1940	Sept.	IBA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
Phleum pratense L.	Timothy	Nowosad 1939	March	NAA charcoal 10,000 p.p.m.	4	83	33	
Phlox paniculata L.	Summer Perennial Phlox	Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	3	75*	49*	
P. subulata L.	Ground Pink	Tincker 1938	June	IAA 50 p.p.m. 24 hrs.	2	—	—	20 per cent. more cuttings rooted
Photinia glabra Maxim.	Photinia	Williams 1943	Dec.	Hormodin	5	60	0	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	5	32	16	Stem cuttings

P. serrulata Lindl.		Williams 1943	Dec.	Hormodin	9	64	0	Leaf bud cuttings
do.		Williams 1943	Dec.	Hormodin	9	70	50	Stem cuttings
P. villosa DC.		Scholz 1937	July	IAA 50 p.p.m. 24 hrs.	5	10	0	
Physocarpus opulifolius Maxim.	Ninebark	Chadwick 1937	Nov.	IBA 50 p.p.m. 40 hrs.	8	90	80	
Picea abies Karst. (*P. excelsa*)	Norway Spruce	Maxon Pickett and Richey 1940	Nov.	IBA 20 p.p.m. 24 hrs. (Hormodin)	16	37*	18*	
do.		Grace 1940	Nov.	IAA talc 1,000 p.p.m.	42	75	50	
P. barryi		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. breweriana S. Wats.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
P. compacta Asselyn.		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc. 12,000 p.p.m.	—	—	—	Beneficial
P. cupressina		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. echinaeformis		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. glauca		Grace 1940	March	IAA talc with organic mercury dust	15	—	—	Injurious
P. glauca var. *conica.*		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. kosteriana		Cox 1937	July Aug.	IAA 100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. mariana		Grace 1940	March	IAA talc with organic mercury	15	—	—	Injurious

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
P. omorika		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Thimann and Delisle 1942	—	IAA 200 p.p.m. 24 hrs.	—	36	4	
do.		Thimann and Delisle 1942	—	IAA 200 p.p.m. 24 hrs. followed by Vit. B_1, 0·5 p.p.m. 24 hrs.	—	66	17	
P. pungens		Maxon, Pickett and Richey 1940	Jan.	IBA 40 p.p.m. 24 hrs. (Hormodin)	12	5*	8*	
do.		Kirkpatrick	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. sitchensis Carr.		Griffith 1940	Dec. March	IBA 25 p.p.m. 24 hrs.	7	100	5	Final count after 23 weeks
Pieris floribunda Benth. and Hook.	Pieris	Skinner 1938	July	IBA 10 p.p.m. 8 hrs.	20	20	0	
Pieris formosa D. Don var. *forestii* Airey-Shaw		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	17	—	—	More cuttings rooted
P. japonica D. Don		Skinner 1938	July	IBA 90 p.p.m. 8 hrs.	16	90	60	Leaf bud cuttings
do.		Skinner 1938	July	IBA 90 p.p.m. 8 hrs.	6	100	80	Stem cuttings
do.		Kirkpatrick 1940	—	IBA 20 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	—	—	—	Beneficial
Pieris 29002 F.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died

Pilea microphylla Liebm.	Pilea	Maxon, Pickett and Richey 1940	Jan.	IBA 5 p.p.m. 24 hrs. (Hormodin)	5	67*	42*	
Pinus bungeana Zucc.	Lace-Bark Pine	Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
P. densiflora Sieb. and Zucc. var. *umbraculifera* Mayr.	Japanese Red Pine	Chadwick 1937	July	IBA 10-80 p.p.m. 15 hrs.	—	—	—	No benefit
P. mugo mughus		Maxon, Pickett and Richey 1940	Jan.	IBA 80 p.p.m. 24 hrs. (Hormodin)	6	30*	0*	Poor results with Nov. and April cuttings
P. mugo slavini		Kirkpatrick 1940	—	IBA 40 and 80 p.p.m. 24 hrs.	—	—	—	Beneficial
P. strobus L.		Snow 1940	Aug.	IBA 25 p.p.m. 6 hrs.	50	48	35	Cuttings from 10-year-old trees
do.		Doran 1941	March	IBA 200 p.p.m. 5 hrs.	12	70	—	Cuttings from lower part of 30-year-old tree
do.		Chadwick 1937	July	IBA 10-80 p.p.m. 24 hrs.	—	—	—	No benefit
Piqueria trinervia. Cav.	Piqueria	Maxon, Pickett and Richey 1940	March	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	93*	—	
do.		Maxon Pickett and Richey 1940	May	IBA 5 p.p.m. 24 hrs. (Hormodin)	2	90*	57*	
Pittosporum dalli	Pittosporum	Tincker 1938	Aug.	IAA 100 p.p.m. 24 hrs.	—	10	0	
Podocarpus nerii-folia Don	Podocarpus	Kirkpatrick 1940	March	IAA 200 p.p.m. 24 hrs.	9-14	100	25	From 6-year-old tree
P. parlatorei		Covas 1940	—	IAA 12-24 hrs.	—	—	—	Beneficial
Polygonum paniculatum	Knotweed	Tincker 1938	July	NAA 33 p.p.m. or IAA 16 p.p.m. 24 hrs.	5	10	0	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Poncirus trifoliata Raf.	Poncirus	Gočolašvili and Maximov 1937	Dec.	IBA 200 p.p.m. 24 hrs.	5	100	0	
do.		Doran 1941	Dec.	NAA 100 p.p.m. 17 hrs.	9	60	0	IBA unsuccessful
do.		Metcalfe and Templeman 1939	Aug.	IBA 50 p.p.m. 24 hrs.	7	—	—	Most cuttings rooted
Populus alba L. var. *bolleana* Lauche	White Poplar	Laibach 1937	—	IAA lanolin 0·5 per cent. paste	24	42	18	
P. alba var. *pyramidalis* Bunge		Laibach 1937	Aug.	IAA 100 p.p.m. 24 hrs.	3	56	20	
P. grandidentata Michx.	Large Toothed Aspen	Snow 1938	March	IBA 10 p.p.m. 27 hrs.	8	67	5	Dormant wood
P. tremuloides Michx.	American Aspen	Snow 1938	March	IBA 10 p.p.m. 27 hrs.	8	67	5	Dormant wood
P. alba × *P. nivea*		Afanasiev 1939	—	IBA 10-20 p.p.m.	—	50	0	From root suckers
P. sp.		Afanasiev 1939	—	IBA 10-20 p.p.m. 48 hrs.	7	4	0	
Potentilla fruticosa L.	Cinquefoil	Laibach 1937	Aug.	IAA 100 p.p.m. 24 hrs.	1	50	0	
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	9	40*	23*	
P. fruticosa L. var. " Bowles "		Metcalfe and Templeman 1940	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	2	—	—	More roots per cutting

P. 28575 F.		Metcalfe and Templeman 1940	June	IAA 50 p.p.m. 24 hrs.	2	—	—	More cuttings rooted
Prunus caroliana Ait.	Mock Orange	Williams 1943	Dec.	Hormodin	13	88	12	Leaf bud cuttings
do.		Williams 1943	Dec.	Rootone	5	50	10	Stem cuttings
P. cerasifera Ehrh. (Myrobalan A)	Cherry Plum	Lek and Krijthe 1937	July	IAA 25 p.p.m. 24 hrs.	4	—	—	Beneficial
do. (Myrobalan B)		Lek and Krijthe 1937	July	IAA 25 p.p.m. 24 hrs.	2	—	—	Beneficial
P. cerasifera var. *pissardii* Koehne		Chadwick 1937	July	IBA 10-80 p.p.m. 18 hrs.	—	—	—	No benefit
P. cerasifera Ehrh. 682 L.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
P. laurocerasus L.	Cherry Laurel	Williams 1943	Dec.	Rootone	9	40	60	Leaf bud cuttings
do.		Williams 1943	Dec.	Rootone	9	100	70	Stem cuttings
P. japonica Hort.	Japanese Plum	Longley 1940	June	IBA 22 p.p.m. 20 hrs. (Auxilin 3)	9	70	33	Lower cuttings respond best
P. nana Stokes	Russian Almond	Longley 1940	June	IBA 22 p.p.m. 20 hrs. (Auxilin 3)	—	—	—	No benefit
P. padus L.	European Bird Cherry	Longley 1939	July	IBA 22 p.p.m. 20 hrs.	—	53	33	
P. subhirtella Miq. var. *autumnalis* Mak.		Metcalfe and Templeman 1939	June July	IAA IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
P. subhirtella Miq. *var. pendula* Tanaka	Japanese Weeping Cherry	Chadwick 1937	July	IBA 10-80 p.p.m. 10 hrs.	—	—	—	No benefit

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
P. tomentosa Thunb.		Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin)	—	34	0	Leaf bud cuttings
do.		Chadwick 1937	June	IBA 10 p.p.m. 6 hrs.	4	84	4	
P. sp. Malling F 12/1	Cherry	Pearse 1939	Aug.	IBA 10 p.p.m. 24 hrs.	6	90	0	Rapidly growing shoots less desirable
P. sp. Malling F 251/1		Pearse 1939	June	IBA 15 p.p.m. 24 hrs.	4	90	50	Rapidly growing shoots less desirable
P. sp. Malling F 251/2		Pearse 1939	June	IBA 15 p.p.m. 24 hrs.	4	100	90	Rapidly growing shoots less desirable
P. sp. Malling F 251/3		Pearse 1939	June	IBA 15 p.p.m. 24 hrs.	4	90	40	Rapidly growing shoots less desirable
P. sp. Brompton	Plum	Pearse 1939	July	IBA 20 p.p.m. 24 hrs.	7	80	10	Slowly growing shoots best
P. sp. Myrobalan B.		Pearse 1939	May	IBA 20 p.p.m. 24 hrs.	3	100	80	Slowly growing shoots best
P. sp. Pershore		Pearse 1939	July	IBA 20 p.p.m. 24 hrs.	7	30	0	Slowly growing shoots best
P. sp. Victoria		Pearse 1939	July	NAA 15 p.p.m. 24 hrs.	7	80	0	Slowly growing shoots best
P. triloba Lindl.	Flowering Almond	Longley 1940	June	IBA 22 p.p.m. 20 hrs. (Auxilin 3)	9	7-57	0	Softwood. Middle cuttings best.
P. triloba Lindl. var. *plena* Dipp.		Metcalfe and Templeman 1939	June	IBA 20 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
do.		Metcalfe and Templeman 1939	July	IBA or NAA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
do.		Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin 3)	—	56	0	

P. triloba Lindl. var. *plena* Dipp.		Yerkes 1938	July	IBA 50-100 p.p.m. 4 hrs.	4	33	0	Terminal buds formed when cuttings taken
P. sp. (Newport Plum)		Longley 1939	July	IBA 22 p.p.m. 20 hrs.	10	81	45	Leaf bud cuttings
Pseudotsuga taxifolia Brit.	Douglas Spruce	Griffith 1940	Dec. March	IBA 50 p.p.m. 24 hrs.	8-17	80	0	Counted after 23 weeks
Pterocarya stenoptera DC.	Pterocarya	Scholz 1937	July	IAA 20 p.p.m. 24 hrs.	10	33	0	
Pterostyrax hispida Sieb. and Zucc.	Pterostyrax	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	47	9	
Pueraria hirsuta Schneid.	Kudzu Vine	Maxon, Pickett and Richey 1940	Oct.	Proprietary preparations	2	60-85*	42-51*	Potassium permanganate gave better results
Punica granatum L.	Pomegranate	Cox 1937	July Aug.	IAA 100 p.p.m. 18 hrs.	—	—	—	Beneficial
Purshia tridentata DC.	Purshia	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Pyracantha coccinea Roem.	Firethorn	Yerkes 1938	Oct.	IBA 30 p.p.m. 4 hrs.	10	81	45	Nearly mature cuttings. July and Aug. cuttings failed
P. coccinea Roem. var. *lalandii* Dipp.		Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
Pyrus communis L. Malling Rootstock C2	Pear	Pearse 1939	July	IBA 20 p.p.m. 24 hrs.	6	90	0	Non-growing shoots from established trees
do.		Pearse 1939	July	IBA 30 p.p.m. 24 hrs.	8	80	0	Non-growing shoots from established trees
P. communis L. Malling Rootstock C3		Pearse 1939	July	IBA 40 p.p.m. 24 hrs.	6	60	0	Non-growing shoots from established trees
P. communis L. Malling Rootstock C4		Pearse 1939	July	NAA 40 p.p.m. 24 hrs.	8	80	0	Non-growing shoots from established trees

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Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
P. gibbsi pauciflora		Chadwick 1937	Nov.	IAA 50 p.p.m. 24 hrs.	7	75	60	
P. crenulata Roem.		Lek and Krijthe 1937	Sept.	IAA 50 p.p.m. 20 hrs.	5	100	0	
Pyrus malus L. var. *eleyi* Hort.	Apple	Yerkes 1938	July	IBA 50 p.p.m. 4 hrs.	5	70	0	Wood from young trees in active growth
P. malus L. var. " Antonovka "		Oliver 1938	June	IBA 10-100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. malus L. var. " Athabasca "		Oliver 1938	June	IBA 10-100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. malus L. var. " Bramley's Seedling "		Pearse 1939	July	IBA 15 p.p.m. 24 hrs.	7	50	0	Cuttings from established trees
P. malus L. var. " Erie "		Oliver 1938	June	IBA 10-100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. malus L. var. " Grimes Golden "		Hitchcock andZimmerman 1939	Nov.	IBA 40 p.p.m. 24 hrs.	—	—	—	Beneficial
P. malus L. var. " Hibernal "		Yerkes 1938	June	IBA 10-100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. malus L. Malling Rootstock No.1		Pearse 1939	June	IBA 20 p.p.m. 24 hrs.	3	100	0	Cuttings from stoolbed shoots
P. malus Malling Rootstock No. 9		Pearse 1939	May	NAA 5 p.p.m. 24 hrs.	3	30	0	Cuttings from bedded rootstocks
P. malus L. var. " Patten Greening "		Yerkes 1938	Aug.	IBA 10-100 p.p.m. 24 hrs.	—	—	—	No cuttings rooted
P. malus L. " Rhode Island Greening "		Hitchcock and Zimmerman 1939	Nov.	IBA 40 p.p.m. 24 hrs. or IBA dip 400-1,000 p.p.m. IBA talc 10,000-25,000 p.p.m.	—	—	—	Beneficial

P. malus L. var. *sylvestris*		Maxon, Pickett and Richey 1940	Nov.	IBA 20 p.p.m. 24 hrs. (Hormodin)	4	30*	0*	Root sprouts
P. pulcherrima Asch. and Graebn. (*Malus floribunda*)	Flowering Crab	Yerkes 1938	July	IBA 10-100 p.p.m. 24 hrs.	—	—	—	All cuttings died
P. pulcherrima *Asch.* and Graebn. var. *arnoldiana* Bailey	Arnold Crab	Doran 1940	June	IBA 50 p.p.m. 20 hrs.	—	60	0	
do.		Chadwick 1937	Aug.	IAA or IBA 100 p.p.m. 21 hrs.	—	—	—	No benefit
P. purpurea		Chadwick 1937	June	IBA 10-50 p.p.m. 12 hrs.	—	—	—	No benefit
Quercus engleriana Seemen	Oak	Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	6	—	—	Better callus. No. cuttings rooted
Q. suber L.	Cork Oak	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Quercus sp.	Red Oak	Thimann and Delisle 1938	—	IAA 400 p.p.m. 24 hrs.	—	82	22	From 4 year old trees. Cuttings from mature trees did not respond
Q. × *Quercus kewensis* Osborn		Metcalfe and Templeman 1938	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	All cuttings died
Raphiolepis umbellata Mak.	Raphiolepis	Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
do.		Metcalfe and Templeman 1939	Sept.	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
Rhamnus frangula L.	Alder Buckthorn	Chadwick 1937	July	IBA 5-20 p.p.m.	—	—	—	No benefit

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Rhododendron altaclarense var. *veitchii* Hort.	Rhododendron	Skinner 1938	June	IBA	—	—	—	No benefit. No cuttings rooted
R. × *Rhododendron altaclarense* Lindl.		Metcalfe and Templeman 1939	June	IAA, IBA or NAA 50 p.p.m. 24 hrs.	5	—	—	All equally well rooted
R. canadense Zabel		Kirkpatrick 1940	June	IBA talc 12,000 p.p.m.	13	25	0	Leaf mallet cuttings
R. canescens Don		Kirkpatrick 1940	June	IBA talc 12,000 p.p.m.	13	75	0	Leaf mallet cuttings
R. catawbiense Pursh		Skinner 1938	July	IBA 80 p.p.m. 24 hrs.	18	100	90	Leaf bud cuttings
do.		Skinner 1938	Aug.	IBA 10 p.p.m. 8 hrs.	12	100	80	Stem cuttings
R. collettianum Aitch and Hemsl.		Kirkpatrick 1940	June	IBA talc 12,000 p.p.m.	—	50	0	Leaf bud cuttings
R. dahuricum L.		Kirkpatrick 1940	July	IBA talc 5,000 p.p.m.	8	100	25	Leaf bud cuttings
R. dahuricum L. var. *sempervirens* Sims		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	21	80	80	
do.		Scholz 1938	July	IAA 50 p.p.m. 24 hrs.	4	33	0	Given 12 hour day
R. decorum Franch.		Skinner 1938	July	IBA 80 p.p.m. 24 hrs.	9	100	20	Leaf bud cuttings
R. floccigerum Franch.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. gandavensis Hort. var. " Bouquet de Flore "		Skinner 1938	June	IBA 10 p.p.m. 10 hrs.	13	80	80	

R. gandavensis Hort. " Domenio Scassi "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	18	60	40	
R. gandavensis Hort. " Gloria Mundi "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	20	71	57	
R. gandavensis Hort. " Grandeur Triomphant "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	15	100	0	
R. gandavensis Hort. " Pucelle "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	18	100	60	
R. gandavensis Hort. " Reine Louise "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	18	83	60	
R. gandavensis Hort. " Rosetta "		Skinner 1938	June	IBA 10 p.p.m. 10 hrs.	15	100	80	
R. gandavemsis Hort. " Ruddy Ghent "		Skinner 1938	June	IBA 10 p.p.m. 10 hrs.	21	17	50	
R. gandavensis Hort. " Souvenir de President Carnot "		Skinner 1938	June	IBA 10 p.p.m. 10 hrs.	22	17	50	
R. gandavensis Hort. " Unique "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	22	50	20	
R. hippophaoides I.B. Balf and W. W. Sm. var. *roseum* Hort.		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. × *Rhododendron impeanum* Hort.		Metcalfe and Templeman 1939	June July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died
R. indicum Sweet var. *balsaminiflorum* Nichols		Metcalfe and Templeman	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. japonicum Suring.		Skinner 1938	June	IBA 10 p.p.m. 24 hrs.	11	90	60	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
R. japonicum Suring. var. *aureum*		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	9	100	100	Rooting quicker and more roots per cutting
R. lutescens		Cox 1937	July Aug.	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
R. maximum L.		Skinner	July	IBA 90 p.p.m. 24 hrs.	13	100	20	Leaf bud cuttings
R. maximum L. var. *roseum*		Kirkpatrick 1940	July	IBA talc 12,000 p.p.m.	10	50	0	Leaf bud cuttings
R. muranthum Turez.		Skinner 1938	July	IBA 10 p.p.m. 8 hrs.	13	100	60	
R. minus Michx.		Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	18	90	10	Leaf bud cuttings. Quicker rooting
do.		Skinner 1938	July	IBA 90 p.p.m. 8 hrs.	14	40	20	Stem cuttings
R. mixtum (hybrids of *R. rustica*) Apelles		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	22	80	0	
R. mixtum " Il Tasso "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	20	100	20	
R. mixtum " Phoebe "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	20	60	20	
R. molle Don		Kirkpatrick 1940	July	IBA talc 2,000 p.p.m.	10	50	0	Leaf bud cuttings
R. molle Don var. *albicans*		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	10	100	0	
R. molle Don " Compte de Gomer "		Skinner 1938	June	IBA	—	—	—	No effective treatment found
R. molle Don " Elizabeth "		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	10	40	25	

R. molle Don "Frère Orban"		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	10	100	20	
R. molle Don "General Brailmont"		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	8	100	100	More roots per cutting
R. molle Don "Mignon"		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	9	100	100	Rooting accelerated
R. mucronulatum Turez.		Kirkpatrick 1940	June	IBA talc 12,000 p.p.m.	7	75	0	Leaf bud cuttings
do.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
do.		Chadwick 1937	Aug.	IAA or IPA 100 p.p.m. 21 hrs.	—	—	—	No benefit
R. myrtilloides		Cox 1937	July Aug.	IAA 100 p.p.m. 24 hrs.	—	—	—	No benefit. Cuttings died
R. occidentale A. Gray "Orange Red"		Metcalfe and Templeman 1939	June	IBA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
R. occidentale A. Gray "White"		Metcalfe and Templeman 1939	June	IBA 50 p.p.m.	5	—	—	More cuttings rooted
R. occidentale A. Gray "Pink"		Metcalfe and Templeman 1939	June	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. ponticum L.		Skinner 1938	July	IBA 40 p.p.m. 24 hrs.	9	80	80	More roots per cutting. Stem cuttings
do.		Skinner 1938	July	IBA 40 p.p.m. 8 hrs.	8	100	80	Leaf bud cuttings
R. pulchrum var. *maxwellii.*		Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	5	100	100	More roots per cutting
R. × *R. praecox* Carr.		Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	18	—	—	More cuttings rooted

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
R. racemosum Franch.		Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	11	100	100	More roots per cutting
R. reticulatum D. Don		Skinner 1938	July	IBA 40 p.p.m. 8 hrs.	5	100	100	More roots per cutting
R. roseum Hort.		Skinner 1938	July	IBA 80 p.p.m. 8 hrs.	18	40	0	
R. russatum I.B. Balf. and Forrest var. *roseum* Hort.		Metcalfe and Templeman 1939	July	IAA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. schippenbachii Maxim.		Kirkpatrick 1940	May	IBA talc 12,000 p.p.m.	11	75	0	Leaf bud cuttings
R. vaseyi A. Gray		Skinner 1938	June	IBA 10 p.p.m. 8 hrs.	15	60	30	
do.		Kirkpatrick 1940	June	IBA talc 2,000 p.p.m.	11	75	0	Leaf bud cuttings
R. viscosepalum var. *daviesii* Rehd.		Skinner 1938	June	IBA 90 p.p.m. 10 hrs.	10	100	80	
R. viscosum Torr.		Skinner 1938	July	IBA 90 p.p.m. 24 hrs.	4	100	100	More roots per cutting
do.		Kirkpatrick 1940	June	IBA-talc 15,000 p.p.m.	7	50	0	Leaf bud cuttings
R. sp. " Davies II "		Metcalfe and Templeman 1939	June	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
R. " Dr Chas. Bauman "		Metcalfe and Templeman 1939	June	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit Many cuttings died
R. " Flamboyant "		Metcalfe and Templeman 1939	June	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died

Rhodotypos kerriodes Sieb. and Zucc.	Rhodotypos	Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin)	—	33	0	Leaf bud cuttings
do.		Chadwick 1937	July	IBA 10 p.p.m. 24 hrs.	4	76	0	
Ribes alpinum L.	Alpine Currant	Chadwick 1937	June	IBA 80 p.p.m. 12 hrs.	5	44	0	
R. alpinum L. var. *variegatum*		Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin)	—	92	60	
R. grossularia L.	Gooseberry	Tincker 1938	Oct.	NAA 10 p.p.m. 24 hrs.	—	—	—	20 per cent. more cuttings rooted
R. sanguineum Pursh " King Edward VII "	Flowering Currant	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	4	—	—	No benefit. All equally rooted
Robinia pseudacacia L.	False Acacia	Stoutemyer 1940	—	NAA 100 p.p.m. 24 hrs.	—	75	—	Hardwood. Callused before treatment
Rosa canina L.	Dog Rose	Brandon 1939	June	IAA 20 p.p.m. 24 hrs.	—	7	0	Softwood cuttings
do.		Brandon 1939	Dec.	IAA 100 p.p.m. 24 hrs.	—	54	58	Hardwood cuttings
R. ecae Aitch.		Scholz 1937	July	IAA 20 p.p.m. 24 hrs.	5	67	25	
R. indica var. *odorata* Lindl.	Tea Rose	Maxon, Pickett and Richey 1940	Nov.	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	85*	0*	
R. manetti Hort.	Manetti Rose	Maxon, Pickett and Richey 1940	March	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	63*	15*	
R. moschata Mill. var. *floribunda*	Musk Rose	Brandon 1939	Dec.	IAA 20 p.p.m. 24 hrs.	—	16	84	Hardwood cuttings
R. multiflora Thunb.		Kirkpatrick 1940	Summer Autumn	IBA talc 2,000 p.p.m.	—	—	—	Beneficial when rooting medium at 65° to 75° F.
R. multiflora Thunb. " Chenaults "		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	10	20*	20*	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
R. multiflora Thunb. " Climbing American Beauty "		Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	9	25*	13*	
R. multiflora Thunb. " Dorothy Perkins "		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	3	80*	43*	
R. multiflora Thunb. " Excelsa "		Maxon, Pickett and Richey 1940	April	IBA 20 p.p.m. 24 hrs. (Hormodin)	6	43*	30*	
R. multiflora Thunb. " Seabrooks "		Brandon 1939	Dec.	IAA 20 p.p.m. 24 hrs.	—	64	18	Hardwood cuttings
R. multiflora Thunb. " Tausend Schoen "		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	28*	0*	
R. multiflora* × *R. blanda		Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	3	38*	0*	
R. odorata Sweet	Tea Rose	Yerkes 1938	June	IBA 30-100 p.p.m. 18 hrs.	2	95	89	Easily rooted at any time
R. polyantha Hort. " Kluis Scarlet "		Maxon, Pickett and Richey 1940	April	IBA 5 p.p.m. 24 hrs. (Hormodin)	5	97*	19*	
R. sericea Lindl. var. *pteracantha*		Scholz 1937	July	IAA 20 p.p.m. 24 hrs.	4	27	0	
R. willmottiae Baker		Brandon 1939	Dec.	IBA 20 p.p.m. 24 hrs.	—	—	—	No benefit. Hardwood cuttings
R. " Dizzy Bee "		Warner and Went 1939	Jan.	IAA 200 p.p.m. 24 hrs.	3	100	0	

R. " Crimson Conquest "		Metcalfe and Templeman 1939	July	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
R. " Ellen Poulsen "		Oliver 1938	June	IBA 40 p.p.m. 24 hrs.	—	40	0	
R. " Kirsten Poulsen "		Brandon 1939	Dec.	IAA 20 p.p.m. 24 hrs.	—	57	0	Hardwood cuttings
R. " Golden Rambler "		Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	5	—	—	No benefit. All equally rooted
R. " Paul's Scarlet Climbing "		Brandon 1939	Dec.	IAA 100 p.p.m. 24 hrs.	—	24	26	Hardwood cuttings
R. sp. (Several climbing varieties)		Kirkpatrick 1940	July Aug.	IBA 5 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	—	—	—	Beneficial when temperature of rooting medium 65-75° F.
R. sp. (Hybrid Teas, Garden varieties)		Kirkpatrick 1940	Aug.	IBA 2·5 p.p.m. 24 hrs. or IBA talc 2,000 p.p.m.	2-3	—	—	Beneficial when temperature of rooting medium 65-75° F.
R. sp. (Hybrid Teas, Greenhouse varieties)		Kirkpatrick 1940	After flowering	IBA 1·25-2·5 p.p.m. 24 hrs. or IBA talc 1,000-2,000 p.p.m.	2-3	—	—	Effective when temperature of rooting medium 65-75° F.
Rubus deliciosus James	Rocky Mountain Flowering Raspberry	Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin)	—	0	0	Leaf bud cuttings
Saintpaulia sp.		Warner and Went 1939	Feb.	IAA 50 p.p.m. 16 hrs.	3	100	100	More roots per cutting
Salix discolor Muhl.	Pussy Willow	Chadwick 1937	June	IBA 50 p.p.m. 12 hrs.	3	72	36	
S. glauca L.		Cox 1937	July Aug.	IAA 100 p.p.m. 18 hrs.	3	—	—	Rooting delayed
S. glauca S. *cistus*		Cox 1937	July Aug.	IAA 100 p.p.m. 18 hrs.	4	—	—	Rooting delayed
S. incana Schrank		Chadwick 1937	June	IBA 10 p.p.m. 6 hrs.	3	96	60	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

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						Treated	Control	
Salvia apiana Jepson	Sage	Warner and Went 1939	March	IAA 200 p.p.m. 36 hrs.	3	100	0	
S. mellifera Greene	Black Sage	Warner and Went 1939	Feb.	IAA 200 p.p.m. 24 hrs.	2	100	0	
do.		Warner and Went 1939	March	IAA 200 p.p.m. 24 hrs.	2	100	63	
Sambucus canadensis L.	American Elder	Grace 1940	Nov.	NAA talc 1,000 p.p.m.	9	87	47	Dormant cuttings
S. racemosa L. var. *laciniata* W. Koch	Red Berried Elder	Longley 1939	July	IBA 22 p.p.m. 20 hrs, (Auxilin)	—	100	80	Leaf bud cuttings
Sansevieria guiniensis Willd.	Bowstring Hemp	Laibach 1937	Nov.	IAA lanolin 0·5 per cent. paste	6	76	12	
Santolina chamaecyparissus L.	Lavender Cotton	Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Schizophragma hydrangeoides Sieb. and Zucc.	Schizophragma	Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	18	—	—	More cuttings rooted
Sciadopitys verticillata Sieb. and Zucc.	Umbrella Pine	De France 1939	Jan.	IBA 20 p.p.m. 20 hrs.	—	70	0	
Senecio cineraria DC.	Groundsel Dusty Miller	Maxon, Pickett and Richey 1940	Jan.	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	60*	35*	
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	2	45*	12*	
S. greyii Hook. f.		Laibach 1947	—	IAA	—	—	—	Treated cuttings rooted slightly better

S. mikanoides Otto	German Ivy	Maxon, Pickett and Richey 1940	Jan.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	2	95*	45*	
Sequoia gigantea DC.	California Big Tree	Kirkpatrick 1940	Jan.	IBA 40 and 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
S. sempervirens Endl.	California Redwood	Thimann 1942	March	IAA 100 p.p.m. 24 hrs.	11	34	0	Cuttings from 10-year-old tree
Serissa foetida Lam.	Serissa	Tajima 1937		IAA 10 p.p.m. 24 hrs.	—	—	—	Beneficial
Sinojackia rehderiana Hu.	Sinojackia	Metcalfe and Templeman 1939	June	IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted
Sinowilsonia henryi Hemsl.	Sinowilsonia	Metcalfe and Templeman 1939	Aug.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Skimmia sp.	Skimmia	Hubert and Beke 1938	Nov.	IAA 100 p.p.m. 8 hrs.	3	90	30	More roots per rooted cutting
Spiraea arguta Zabel	Spiraea	Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	5	63*	8*	More roots per rooted cutting
S. × *Spiraea arguta* Zabel		Metcalfe and Templeman 1939	Sept.	IAA or IBA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted. July cuttings died
S. billiardii Herincq		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	4	66*	16*	
S. bumalda Burvenich		Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	9	65*	13*	
S. prunifolia Sieb. and Zucc.		Laibach 1937	—	IAA	—	—	—	Slight benefit
S. prunifolia Sieb. and Zucc. var. *plena* Schneid.		Metcalfe and Templeman 1939	Sept.	IAA 50 p.p.m. 24 hrs.	4-6	—	—	More cuttings rooted

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Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
S. thunbergii Sieb. and Zucc.		Laibach 1937	—	IAA	—	—	—	Slight benefit
Stachyurus chinensis Franch.	Stachyurus	Metcalfe and Templeman 1939	June July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. Many cuttings died
Stephanandra flexuosa Sieb. and Zucc.	Stephanandra	Chadwick 1937	July	IBA 10 p.p.m. 6 hrs.	3	88	88	
Stewartia koreana Nakai	Stewartia	Metcalfe and Templeman 1939	June	IBA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted. July cuttings did not respond
S. malachodendron L.		Metcalfe and Templeman 1939	June	NAA 20 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
S. pseudo-camellia		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	50	33	
Styrax hemsleyana Diels	Storax	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
S. japonica Sieb. and Zucc.		Yerkes 1938	July	IBA 50 p.p.m. 4 hrs.	3	100	10	Terminal buds forming when cuttings taken
S. philadelphoides Perkins		Metcalfe and Templeman 1939	Sept.	NAA 50 p.p.m. 24 hrs.	—	—	—	More cuttings rooted. More roots per cutting
Symphoricarpos albus var. ***laevigatus*** Blake	Snowberry	Grace 1941	Sept.	IAA talc 1,000 p.p.m.	6	74	54	Softwood cuttings
Symplocos paniculata Wall.	Symplocos	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	4	17	0	

Syringa chinensis Willd.	Lilac	Laibach 1937		IAA lanolin 1,250 p.p.m. paste	11	15	0	
S. *emodi* Wall.		Kirkpatrick 1939	April	IBA 40 p.p.m. 24 hrs.	5	75	14	
S. *formosissima* Nakai		Scholz 1937	July	IAA 50 p.p.m. 48 hrs.	10	33	0	
S. *henryi* Schneid		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	3	100	25	
S. *japonica* Decne		Longley 1939	July	IBA 22 p.p.m. 20 hrs. (Auxilin)	—	0	0	
S. *josikaea* Jacq.		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	5	75	25	
S. *meyeri* Schneid.		Chadwick 1937	July	IBA 80 p.p.m. 3 hrs.	8	44	12	
S. *persica* L.		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	5	100	0	
S. *prestoniae* "Calphurnia"		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	80	20	
S. *prestoniae* "Celia"		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	40	0	
S. *prestoniae* "Charmian"		Scholz 1937	July	IAA 50 p.p.m. 24 hrs.	5	88	17	
S. *prestoniae* "Jessica"		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	20	0	
S. *prestoniae* "Miranda"		Oliver 1938	July	IBA 40 p.p.m. 24 hrs.	7	60	20	
S. *prestoniae* "Virgilia"		Oliver 1938	June	IBA 40 p.p.m. 24 hrs.	6	20	0	
S. *tomentella*		Kirkpatrick 1939	April	IBA 40 p.p.m. 24 hrs.	4	100	20	
S. *villosa* Vahl		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	3	75	0	
do.		Chadwick 1937	June	IBA 50 p.p.m. 6 hrs.	7	72	80	

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
S. vulgaris L.		Warner and Went 1939	March	IAA 200 p.p.m. 23 hrs.	3	33	—	Hardwood cuttings
do.		Warner and Went 1939	March	IAA 200 p.p.m. 23 hrs.	3	88	10	Softwood cuttings
S. vulgaris L. " Adelaide Dunbar "		Kirkpatrick 1939	May	IBA 60 p.p.m. 24 hrs.	9	75	0	
S. vulgaris L. " Antoine Buckner "		Kirkpatrick 1939	May	IBA 20 p.p.m. 24 hrs.	9	75	0	
S. vulgaris L. " Arthur Wm. Paul "		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	8	50	0	
S. vulgaris L. " Belle de Nancy "		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	43	17	
S. vulgaris L. " Charles Joly "		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	10	80	0	
do.		Maxon, Pickett and Richey 1940	May	IBA 80 p.p.m. 24 hrs. (Hormodin)	9	58*	0*	
S. vulgaris L. " Condorcet "		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	10	75	20	
S. vulgaris L. " Decaisne "		Kirkpatrick 1939	May	IBA 60 p.p.m. 24 hrs.	8	100	0	
S. vulgaris L. " Duc de Massa "		Kirkpatrick 1939	April	IBA 40 p.p.m. 24 hrs.	11	75	0	
S. vulgaris L. " Louvois "		Yerkes 1932	May	IBA 50 p.p.m. 24 hrs.	9	49	41	Softwood cuttings. No results with hardwood
S. vulgaris L. " Maureen "		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	40	0	

S. vulgaris L. " Mme Casimir " Perier		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	10	30	0	
do.		Kirkpatrick 1939	May	IBA 60 p.p.m. 24 hrs.	7	50	0	
S. vulgaris L. " Mme Florent Stepman "		Kirkpatrick 1939	May	IBA 60 p.p.m. 24 hrs.	9	100	0	
S. vulgaris L. " Mme Lemoine "		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	5	43	0	
S. vulgaris L. " Mont Blanc "		Kirkpatrick 1939	May	IBA 20 p.p.m. 24 hrs.	9	50	0	
S. vulgaris L. " Muriel "		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	20	0	
S. vulgaris L. " Peggy "		Yerkes 1938	June	IBA 80 p.p.m. 24 hrs.	6	40	0	
S. vulgaris L. " Perle von Teltow "		Kirkpatrick 1939	May	IBA 20 p.p.m. 24 hrs.	8	100	0	
S. vulgaris L. " President Grevy "		Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	10	80	40	
do.		Chadwick 1937	June	IBA 30 p.p.m. 6 hrs.	7	32	24	
S. vulgaris L. " President Poincare "		Kirkpatrick 1939	May	IBA 40 p.p.m. 24 hrs.	9	50	0	
S. vulgaris L. " Prof. Sargent "		Kirkpatrick 1939	May	IBA 60 p.p.m. 24 hrs.	8	75	0	
S. vulgaris L. Thunb.		Oliver 1938	June	IBA 80 p.p.m. 24 hrs.	6	40	0	
do.		Oliver 1938	July	IBA 20 p.p.m. 24 hrs.	6	60	20	
Tamarix gallica L.	Tamarisk	Laibach 1937	—	IAA	—	—	—	Slight improvement

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Taxus baccata L. var. *fastigiata* Loud.	Yew	Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. baccata L. var. *glauca* Carr.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. baccata var. *imperialis* Hort.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. baccata var. *repandens* Hort.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Chadwick 1937	Jan.	IAA 5-100 p.p.m. 12 hrs.	—	—	—	No benefit
T. baccata var. *washingtonii* Beissn.		Chadwick 1937	Jan.	IAA 50 p.p.m. 12 hrs.	13	80	70	
T. cuspidata Sieb. and Zucc.		Chadwick 1937	Jan.	IAA 50 p.p.m. 12 hrs.	13	100	85	
do.		Chadwick 1937	June	IBA 30 p.p.m. 6 hrs.	14	90	77	
do.		Oliver 1938	July	IBA 80 p.p.m. 24 hrs.	8	60	0	
do.		Yerkes 1938	Dec.	IBA 50-80 p.p.m. 22 hrs.	8	95	30	
do.		Hitchcock and Zimmerman 1936	—	NAA 40 p.p.m. 24 hrs.	9	80	0	
do.		Grace and Farrar 1941	—	NBA talc 500-2,000 p.p.m.	11	20-43	65	Treated cuttings had more roots
T. cuspidata Sieb. and Zucc. var. *brevifolia* Hort.		Maxon, Pickett and Richey 1940	Nov.	IBA 40 p.p.m. 24 hrs. (Hormodin)	17	65*	0*	

T. cuspidata Sieb. and Zucc. var. *brevifolia* Hort.		Maxon, Pickett and Richey 1940	April	IBA 20 p.p.m. 24 hrs. (Hormodin)	12	48*	45*	
T. cuspidata Sieb. and Zucc. var. *capitata*		Chadwick 1937	July	IBA 10-80 p.p.m. 24 hrs.	—	—	—	No benefit
T. cuspidata Sieb. and Zucc. var. *compacta*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. cuspidata Sieb. and Zucc. var. *nana*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Chadwick 1937	Jan.	IAA 50 p.p.m. 12 hrs.	13	50	30	
T. media var. *hatfieldi*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. media var. *hicksii*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Chadwick 1937	Jan.	IAA 50 p.p.m. 12 hrs.	13	80	30	
do.		Chadwick 1937	June	IBA 50 p.p.m. 6 hrs.	14	40	43	
do.		Maxon, Pickett and Richey 1940	Mar. Apr.	IBA 20-80 p.p.m. 24 hrs. (Hormodin)	11-16	83*	3-48*	
Telanthera versicolor Regel	Alternanthera	Maxon, Pickett and Richey 1940	Oct.	IBA 2·5 p.p.m. 24 hrs. (Hormodin)	3	97*	80*	
Teucrium chamaedrys L.	Wall Germander	Maxon, Pickett and Richey 1940	Jan.	IBA 80 p.p.m. 24 hrs. (Hormodin)	5	100*	0*	
T. fruticans L.		Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	3	—	—	More cuttings rooted

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Thea sp.	Tea	Emden 1939	—	IAA 100 p.p.m. 36 hrs.	6	80	0	Lanolin paste ineffective
Thuya occidentalis L.	Common Arborvitae	Maxon, Pickett and Richey 1940	Jan.	IBA 40 p.p.m. 24 hrs. (Hormodin)	6-26*	26-80*	1-18*	
do.		Maxon, Pickett and Richey 1940	Oct.	IBA 40 p.p.m. 24 hrs. (Hormodin)	5-18*	18-35*	5-28*	
do.		Oliver 1938	July	IBA 40 p.p.m. 24 hrs.	6	40	0	
T. occidentalis L. var. *filiformis* Beissn.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. occidentalis L. var. *globosa* Beissn.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
do.		Yerkes 1938	Oct.	IBA 60-80 p.p.m. 20 hrs.	10	85	25	
T. occidentalis L. var. *globosa nana*		Kirkpatrick 1940	—	IBA 40-80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. occidentalis L. var. *hooperi*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. occidentalis L. var. *hoveyi*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. occidentalis L. var. *hudsonica*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. occidentalis L. var. *pyramidalis*		Oliver 1938	June	IBA 100 p.p.m. 24 hrs.	8	80	0	
T. occidentalis L. var. *spiralis*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial

T. occidentalis L. var. *wareana* Beissn.		Maxon, Pickett and Richey 1940	Oct.	IBA 40 p.p.m. 24 hrs. (Hormodin)	18	58*	18*	
do.		Maxon, Pickett and Richey 1940	Dec.	IBA 40 p.p.m. 24 hrs. (Hormodin)	17	53*	8*	
do.		Maxon, Pickett and Richey 1940	March	IBA 20 p.p.m. 24 hrs. (Hormodin)	19	20*	0*	
do.		Oliver 1938	June	IBA 100 p.p.m. 24 hrs.	7	80	0	
T. orientalis L. *aurea nana* Hort.		Chadwick 1937	July	IBA 10-80 p.p.m. 12 hrs.	—	—	—	No benefit
T. plicata Don		Yerkes 1938	Jan.	IBA 80-100 p.p.m. 22 hrs.	9	79	0	
Thujopsis dolabrata Sieb. and Zucc.	Thujopsis	Tincker 1938	Summer	IAA 50 p.p.m. 24 hrs.	12	—	—	45 per cent. more rooted
Thunbergia sp.	Thunbergia	Covas 1940		IAA 12-24 hrs.	—	—	—	Beneficial
Trachelospermum jasminoides Lem.	Star Jasmine	Metcalfe and Templeman 1939	July	NAA 50 p.p.m. 24 hrs.	4	—	—	More cuttings rooted
Tradescantia sp.	Spiderwort	Cooper 1935	—	IAA lanolin 0·5 per cent. paste	3	—	—	More roots per cutting
Trifolium pratense L.	Common Red Clover	Nowosad 1939	March	NAA 10 p.p.m. 12 hrs. or NAA talc 50 p.p.m.	3	—	—	Beneficial
Tsuga canadensis Carr.	Common Hemlock	Yerkes 1938	Jan.	IBA 100 p.p.m. 22 hrs.	9	79	0	
T. canadensis Carr. var. *dawsoniana*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. canadensis Carr. var. *minima*		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
T. canadensis Carr. var. *pendula* Parsons		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial

INDEX OF TYPICAL RESULTS OBTAINED WITH CUTTINGS OF VARIOUS SPECIES—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
T. heterophylla Sarg.		Lek and Krijthe 1937	Jan.	IAA	—	—	—	Beneficial
T. jeffreyi Henry		Metcalfe and Templeman 1939	Sept.	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
T. sieboldii Carr.		Kirkpatrick 1940	—	IBA 40 or 80 p.p.m. 24 hrs. or IBA talc 12,000 p.p.m.	—	—	—	Beneficial
Ugni molinae Turez.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	5	58	17	
Ulex europaeus L. var. *plenus* Schneid.	Gorse	Metcalfe and Templeman 1939	July	IAA, IBA or NAA 50 p.p.m. 24 hrs.	—	—	—	No benefit. All cuttings died
Ulmus americana L.	White Elm	Doran 1941	June	IBA 50 p.p.m. 24 hrs.	5	94	23	
U. pumila L.		Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
do.		Watkins 1938	—	IBA 80 p.p.m. 24 hrs. (Hormodin)	4	60	0	
U. sp. ?	Evergreen Elm	Warner 1938	—	IAA 200 p.p.m. 24 hrs.	3	100	0	
Vaccinium corymbosum L'Herit.	Blueberry	Scholz 1937	July	IAA 100 p.p.m. 48 hrs.	6	50	0	
V. corymbosum Kubel. " Pioneer " " Adams " and " Cabot "		Johnson 1939	April	IBA 20-80 p.p.m. 16-24 hrs. (Hormodin)	—	—	—	No benefit

Vangueria edulis Vahl.	Vangueria	Hubert and Beke 1938	—	IAA 100 p.p.m. 22 hrs.	—	—	—	No benefit
Verbena hybrida	Verbena	Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	1	65*	5*	
V. laciniata		Maxon, Pickett and Richey 1940	Oct.	IBA 10 p.p.m. 24 hrs. (Hormodin)	2	80*	37*	
V. rigida		Maxon, Pickett and Richey 1940	Oct.	IBA 5 p.p.m. 24 hrs. (Hormodin)	2	89*	32*	
Veronica longifolia L. var. *subsessilis* Miq.	Veronica	Maxon, Pickett and Richey 1940	Oct.	IBA 20 p.p.m. 24 hrs. (Hormodin)	3	60*	2*	Hardwood cuttings
Viburnum americanum	Cranberry	Chadwick 1937	Aug.	IBA 100 p.p.m. 24 hrs.	5	92	88	
V. carlesii Hemsl.		Scholz 1939	July	IAA 50 p.p.m. 48 hrs.	7	91	20	
do.		Chadwick 1937	June	IBA 30 p.p.m. 6 hrs.	2	64	15	
V. cassinoides L.	Appalachian Tea	Yerkes 1938	June	IBA 30-50 p.p.m. 4 hrs.	4	30	30	
V. dentatum L.	Arrow Wood	Yerkes 1938	June	IBA 30-50 p.p.m. 4 hrs.	6	100	80	Rooted best from growing wood
do.		Chadwick 1937	June	IBA 30 p.p.m. 16 hrs.	3	96	56	
do.		Chadwick 1937	Aug.	IBA 10 p.p.m. 24 hrs.	5	95	30	
V. dilatatum Thunb.		Yerkes 1938	June	IBA 30-100 p.p.m. 2 hrs.	4	100	70	Actively growing wood best
V. grandiflorum Wall.		Metcalfe and Templeman 1939	July	IAA 50 p.p.m. 24 hrs.	5	—	—	More cuttings rooted
V. lantana L.	Wayfaring Tree	Oliver 1938	July	IBA 40 p.p.m. 24 hrs.	6	20	0	
do.		Yerkes 1938	June	IBA 50 p.p.m. 4 hrs.	4	66	58	

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
V. lantana L.		Chadwick 1937	July	IBA 10 p.p.m. 6 hrs.	3	88	88	
V. lentago L.	Sheep Berry	Chadwick 1937	July	IBA 5-20 p.p.m. 24 hrs.	—	—	—	No benefit
V. opulus L.	Guelder Rose	Chadwick 1937	June	IBA 10 p.p.m. 6 hrs.	3	100	76	
V. opulus var. *nanum* Jacq.		Chadwick 1937	July	IBA 30 p.p.m. 5 hrs.	4	100	96	
V. rhytidophyllum Hemsl.		Chadwick 1937	July	IBA 5-20 p.p.m. 18 hrs.	—	—	—	No benefit
V. sieboldii Miq.		Yerkes 1939	June	IBA 30-50 p.p.m. 4 hrs.	4	92	0	
do.		Chadwick 1937	July	IBA 10 p.p.m. 24 hrs.	4	84	48	
V. tinus L.	Laurustinus	Hubert and Beke 1938	Dec.	IAA 50 p.p.m. 6 hrs.	2	100	30	Quicker rooting and more roots per cutting
V. tomentosum Thunb.		Chadwick 1937	July	IBA 30-50 p.p.m. 20 hrs.	—	33	0	
do.		Yerkes 1938	June	IBA 30 to 50 4 hrs.	4	91	92	
do.		Scholz 1937	July	IAA 50 p.p.m. 24 hrs.	5	100	100	
V. tomentosum Thunb. var. *mariesii* Veitch		Metcalfe and Templeman 1939	July	IAA or IBA 50 p.p.m. 24 hrs.	2	—	—	More cuttings rooted
V. wrightii Miq.		Yerkes 1938	June	IBA 30-100 p.p.m. 4 hrs.	4	100	59	
Vinca minor L.	Common Periwinkle	Chadwick 1937	Aug.	IBA 10 p.p.m. 24 hrs.	3	100	4	
Viola cornuta L.	Viola	Tincker 1938	July	IBA 8 p.p.m. or NAA 25 p.p.m. or IAA 25 p.p.m. 24 hrs.	2	—	—	30 per cent. more cuttings rooted

Vitex agnus castus L.	Hemp Tree	Scholz 1937	July	IAA 100 p.p.m. 24 hrs.	6	100	0	
do.		Hubert and Beke 1938	Dec.	IAA 100 p.p.m. 22 hrs.	3	92	75	Basal cuttings rooted best
V. negundo L. var. *incisa* Clarke		Chadwick 1937	July	IBA 20 p.p.m. 24 hrs.	3	64	4	
Vitis rotundifolia Michx.	Muscadine Grape	Yerkes 1938	Aug.	IBA 20 p.p.m. 20 hrs.	3	44	0	Cuttings third to sixth node from growing tip best
Vitis vinifera L. var. 41 B " Berlandieri "	European Grape	Evenari 1938	March	IAA lanolin paste	6	55	0	
do.		Evenari 1938	March	IAA 150 p.p.m. 44 hrs.	6	80	0	
V. vinifera L. var. " Chasselas "		Evenari 1938	March	IAA	8	100	100	Crystals applied to apical cut surface
V. vinifera L. var. " Concord "		Warner and Went 1939	March	IAA 100 p.p.m. 24 hrs.	5	100	100	More roots per cutting
V. vinifera L. var. " Empress "		Warner and Went 1939	March	IAA 200 p.p.m. 24 hrs.	5	100	100	More roots per cutting
V. vinifera L. var. " Hamburger Musket "		Evenari 1938	Feb.	IAA lanolin paste	3	100	0	Apical application
V. vinifera L. var. (" Mourvèdre " × " Rupestris 1202 ")		Evenari 1938	March	IAA lanolin paste	6	100	80	
V. vinifera L. var. " Rupestris 1202 "		Evenari 1938	March	IAA 150 p.p.m. 44 hrs.	6	100	80	
V. vinifera L. var. " Rupestris du Lot "		Evenari 1938	March	IAA lanolin paste	6	80	15	Basal application
V. vinifera L. var. " Thompson "		Warner and Went 1939	March	IAA 200 p.p.m. 24 hrs.	4	100	70	More roots per cutting
Wisteria sinensis Sweet	Wisteria	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	100	44	Cuttings planted dry rooted 60 per cent.

Index of Typical Results Obtained with Cuttings of Various Species—*Continued*

Scientific Name	Common Name	Author(s)	Month cuttings taken	Treatment	Rooting Time Weeks	Percentage rooted		Remarks
						Treated	Control	
Wisteria sinensis Sweet		Lek and Krijthe 1937	July	IAA 100 p.p.m. 12 hrs.	4	100	0	
W. sinensis Sweet var. *albiflora* Lemaire		Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	9	70	9	
do.		Warner and Went 1939	May	IAA 200 p.p.m. 24 hrs.	3	100	0	
Zelkova serrata Makino	Zelkova	Scholz 1937	July	IAA 200 p.p.m. 24 hrs.	4	91	0	

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